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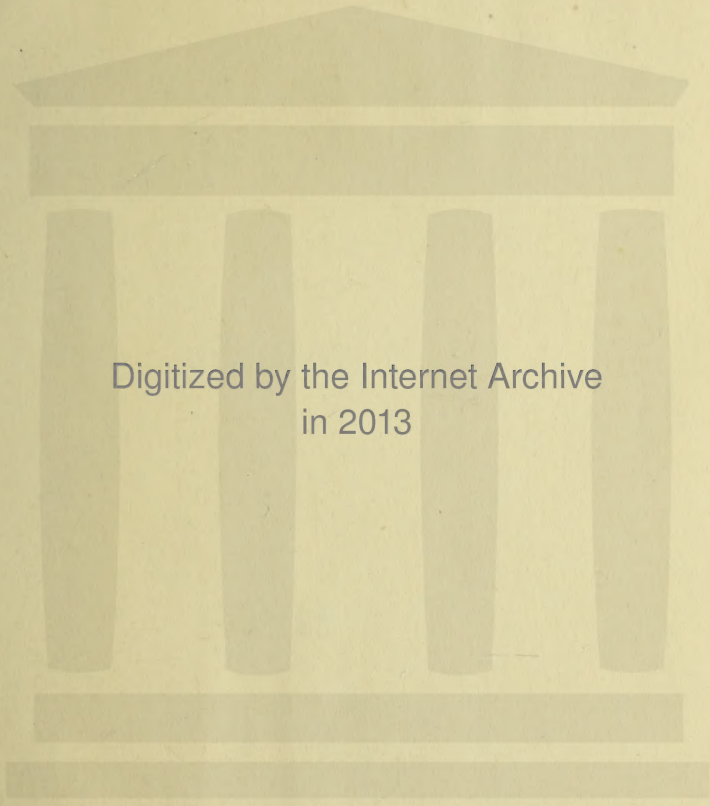

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VOL. 7. JANUARY–FEBRUARY, 1915. NO. 1.

THE EARLY AGRICULTURAL HISTORY OF TIMOTHY.[1]

CHARLES V. PIPER AND KATHERINE S. BORT.

OFFICE OF FORAGE CROP INVESTIGATIONS, U. S. DEPARTMENT OF AGRICULTURE, WASHINGTON, D. C.

Timothy is by far the most important hay grass cultivated in America and for a century at least has occupied this economic position. A peculiar interest attaches to this grass because it was first cultivated in this country. Owing perhaps to this fact nearly every American writer who has discussed the crop has given an account of its early history. These published narratives show, however, many discrepancies in details, as may be seen in the extracts here quoted.

Wiggins,[2] writing in 1840, gives the history as follows:

"Timothy is a well-known favourite and native grass of the middle and northern states; it also flourishes well in the Carolinas, whence it was introduced into England by Timothy Hudson, about the year 1780. It is known in English practice as the meadow cat's-tail or timothy grass. In New England it is called herd's grass; while in other sections of the United States it is known as the herd's of the north, or red-top timothy."

Flint,[3] a quarter of a century later, has the following less inaccurate account:

"The name of Timothy, by which it is more generally known over the country, was obtained from Timothy Hanson, who is said to have cultivated it extensively, and to have taken the seed from New York to Carolina. Its

[1] Received for publication Jan. 7, 1915.

[2] Wiggins, F. S., American Farmers Instructor, p. 228. 1840.

[3] Flint, Charles L., Grasses and Forage Plants, p. 34. 1864.

culture was, according to some accounts, introduced into England, from Virginia by Peter Wynche, about the years 1760 or 1761.

"It is frequently called Herd's grass in New England and New York, and this was the original name under which it was cultivated; it was derived from a man of that name, who, according to Jared Eliot, found it growing wild in a swamp in Piscataqua, N. H., more than a century and a half ago, and began to cultivate it."

Vasey[4] in 1884 makes this statement about the matter:

"This grass, as known in cultivation, is supposed to have been introduced from Europe, but it is undoubtedly indigenous in the mountain regions of New England, New York, and the Rocky Mountains. It is said that about the year 1711 a Mr. Herd found this grass in a swamp in New Hampshire and cultivated it. From him it took the name of Herd's grass. About the year 1720 it was brought to Maryland by Timothy Hanson and received the name of Timothy grass."

In the works of more recent writers there is no greater concordance as to the details of its early history, as the following quotations make manifest:

"It was called Timothy, after Timothy Hanson, who, in the middle of last century, cultivated it first in Carolina, and later, in Virginia. In 1760, Peter Wynch, President of the Agricultural Society of England, obtained the seed of this species, along with that of several other grasses, from North America. In 1763, it was recommended in the Annual Register and the Museum Rusticum as deserving of more extensive cultivation. Soon after it was brought into notice on the continent by the Agricultural Societies there."—Stebler & Schroter.[5]

"The first name comes from Timothy Hanson, of Maryland, who introduced the grass from England in about 1720. The next name comes from a man by the name of Herd who found it growing in New Hampshire and began its cultivation. In 1760 or 1761 Peter Wynch took seeds of it from Virginia to England."—W. J. Beal.[6]

"It was introduced into Maryland about 1720, from Europe, where it is native, by Timothy Hanson, and hence called Timothy. The other name is said to come from a man by the name of Herd who found it growing in New Hampshire and began its cultivation."—A. S. Hitchcock.[7]

"The name Timothy comes from Timothy Hanson or Hanso, of Maryland, who is said to have introduced the seed from England in 1720 and who is responsible for its distribution through Virginia and Carolina. The name Herd's grass is from John Herd, who is said to have found it growing wild in a swamp in New Hampshire as early as 1700 and began its cultivation, resulting in its distribution through New England and New York."—T. F. Hunt.[8]

[4] Vasey, George, U. S. Dept. Agric., Misc. Report No. 32, p. 63. 1884.

[5] Stebler and Schroter, The Best Forage Plants, p. 52. 1889.

[6] Beal, W. J., Grasses of North America, 1: 103. 1896.

[7] Hitchcock, A. S., in Bailey's Cyclopedia of American Agriculture, 3: 1305. 1903.

[8] Hunt, T. F., Forage and Fiber Crops in America, p. 52. 1907.

While these accounts differ considerably in detail, they are similar enough to suggest a common source. One of these sources is certainly the account by Jared Eliot,[9] written in 1749. This indeed is referred to by Flint. Eliot writes as follows:

"There are two sorts of grass which are natives of the country, which I would recommend; these are *Herd Grass* (known in *Pennsylvania* by the name of *Timothy-grass*) the other is *Fowl Meadow*, sometimes called *Duck Grass*, and sometimes *Swamp-wire* grass. It is said that Herd grass was first found in a swamp in *Piscataqua* by one *Herd*, who propagated the same."

Eliot's statement in this quotation, "known in Pennsylvania by the name of Timothy-grass," was probably based on information he received in a letter from Benjamin Franklin, dated July 16, 1747, to whom he had sent herd-grass seed. Franklin says:

"You made some mistake when you intended to favor me with some of the new valuable grass seed (I think you called it herd-seed), for what you gave me is grown up and proves mere timothy; so I suppose you took it out of a wrong paper or parcel."

The letter of Franklin is still preserved in the Library of Yale University. It is published by Bigelow[10] and by Smyth.[11]

Eliot also mentions the grass in his first essay (l. c., p. 6), written in 1747.

"I then proceeded to sow Grass seed, such as red Clover, foul Meadow-grass, English spear grass and Herd grass."

And again in his third essay (l. c., p. 58),

"In reading Mr. Ellis, I find by him that in England they have got Herd Grass seed from this country, and set a value upon it."

Eliot's reference to Ellis doubtless pertains to William Ellis, a prolific contemporary English writer on agricultural subjects. Apparently the only mention by Ellis[12] and what might well be the basis of Eliot's

[9] Eliot, Jared, Essays upon Field-Husbandry in New England, p. 57. Boston, 1760. (This work comprises six essays which, according to the Library of Congress records, were first printed separately in New London and New York as follows: First essay, written in 1747, printed in 1748; second, printed 1749; third, 1751; fourth, 1753; fifth, 1754; sixth, 1759. The combined essays were published in one volume in 1760. Rev. Jared Eliot, rector of Killingworth, Conn., was a farmer of thirty years' experience, and his essays on the agriculture of New England are among the most important of his day. He was a graduate of Yale, a fellow of the Royal Society, and the teacher of Samuel Johnson, the first president of Kings College.)

[10] Bigelow, John, Letters and Works of Benjamin Franklin, 2: 77. 1887.

[11] Smyth, Albert Henry, Life and Writings of Benjamin Franklin, 2: 310. 1905.

[12] Ellis, William, Agriculture Improv'd: or the Practice of Husbandry Display'd, 1: 106. 1746.

note is the following letter of Ellis to ———— published in 1746.

"I have had some Grass seed from —— in America, called St. Timothy-seed; which is an artificial Grass, that will grow six Feet high, and will mow four or five times in a Summer, in good Ground; I have sowed it in my Garden, and hope to have a good crop of Seed from it: If I have, as I hope, from its being come up very green, I will send you some, if you care for it. A Friend of mine try'd it last Year, with very great Success."

No other mention of timothy has been found in a thorough search through Ellis' writings.

Eliot says, as quoted above, that herd grass was first found in a swamp in Piscataqua by a man named Herd. That there was a family by the name of Herd settled near the mouth of the Piscataqua is confirmed by the following letter, received from the secretary of the New Hampshire Historical Society:

"In the first place the first settlement in New Hampshire was made about 1623 when Mr. David Thompson came to the mouth of the Piscataqua River to make a settlement. This is on the sea coast in what is now Rockingham County and the towns of Dover and Portsmouth were among the earliest towns; consequently I have looked among the records of these, and in Portsmouth about 1653 find that some land was granted 'upon the neck of land by Winacont River Commonly called John Heards necke'; this was in what was called the 'Grant of Pescataway' or 'Piscataqua Patent,' names taken from the river, which is variously spelled. I also find the record of the marriage of Joseph Heard of Dover and Rebecca Richards, on August 9, 1722. Evidently the Heard family was prominent in Dover and Portsmouth, for in the Wentworth genealogy I find a genealogy of some of the Heards. One Tristram Heard was killed by the Indians at Dover in 1623; of his descendants, a Joseph Heard was born in 1692 and a John born 1700 and may have been those mentioned above. The family was connected with the Wentworth family by marriage. Though I can find no record of a person by the name having cultivated timothy, the fact that there were so many of the name living about that date in that section known as the Piscataqua Patent leads me to believe there is some truth to the statement that Mr. Heard cultivated it in New Hampshire." (Letter to C. V. Piper, Aug. 20, 1908.)

In regard to the name timothy, it is so far as the literary evidence goes as old as the name herd grass, and apparently both were well known in 1747, the former being used in Pennsylvania and the latter in Massachusetts. The name timothy has commonly been stated to be derived from one Timothy Hanson. The earliest published statement found to this effect is the following[13] written March 16, 1764, signed "A Member of the Society of Arts."

"This plant was first taken notice of in North America, and seems to be a native of Virginia, where it grows, without cultivation, to a great height, on moorish, swampy grounds.

[13] Museum Rusticum et Commerciale, 2: 61. 1764.

"Some years ago the seeds of this plant were carried from Virginia, by one Mr. Timothy Hanson, to North Carolina, where it is now cultivated by the inhabitants; and from this circumstance it received the name it now bears."

In the same volume, page 161, is a letter written to the editor, April 4, 1764, by a man signing himself "A Friend to the Public," correcting the statement made in the above letter:

"I must, however, beg leave to set your correspondent right in one particular. "He says, that the timothy grass was brought into North Carolina by Mr. Timothy Hanson, from Virginia; this seems to be a mistake, as I am informed by a friend of mine, who has been in the country, that Mr. Hanson brought the seeds of this grass into Carolina from New York.

"That it may be cultivated in Virginia I make no doubt, as from its great use it must certainly soon spread over almost the whole continent of America. I am informed by the same gentleman, that this grass is, to great advantage, cultivated in some parts of Pensilvania."

Another English publication[14] has this account:

"Rocque has also cultivated another artificial grass called timothy-grass. This was, in the beginning of the year 1763, brought over from Virginia by Mr. Wyche.

"It was called timothy, because it was brought from New York to Carolina by one Timothy Hanson, but if they had a mind to perpetuate the memory of this person, they should surely rather have called it by his sirname than his christian."

The first mention that has been found in an *American* publication connecting the name of Timothy Hanson with the plant is that of Deane[15] in 1790, as follows:

"*Timothy-grass*, a coarse grass, but very agreeable to all sorts of cattle. It grows best on low and moist lands. It is a native of America, though some say it is not peculiar to this country.

"It obtained its name, by being carried from Virginia to North Carolina by one Mr. Timothy Hanson. It is a species of foxtail; and is represented by the Rev. Mr. Eliot to be the same as herdsgrass, which he says was first found at Piscataqua, by one Herd, who propagated it."

In the second edition of Deane's work published in 1797, the name is given as Timothy *Hanso* instead of Hanson—evidently an error in printing.

A man signing himself R., writing to the American Farmer[16] from Felicity Farm, Maryland, March 18, 1820, says:

"For the introduction of timothy grass into the state of Maryland, the farmers are indebted to Timothy Hanson, the father of Jonathan Hanson, who built

[14] Annual Register for the Year 1765, vol. 8, section headed "Projects," p. 143. London, 1766.

[15] Deane, Samuel, The New England Farmer; or Georgical Dictionary, 1st ed., p. 285. 1790.

[16] American Farmer, 2: 38. 1821.

the first Grist Mills on Jones' Falls, now forming a part of the city of Baltimore. This gentleman resided in Baltimore about seventy years ago; and was the first person to bring the grass into cultivation. I believe Mr. Hanson was a native of one of the New England states, but whether he discovered the value of this grass, growing in the neighborhood of his mill, or brought the seed with him, I can not say; but he had certainly the honour of introducing it to the public, and when it first came into fashion, it was called 'Timothy Hanson's grass,' and sold in 'Baltimoretown' by that name. I should like to know how far back it was called Herd's Grass, to the eastward of Maryland. What has become of the Hanson family? Timothy had several sons. Jonathan, was one of your flour inspectors about the year 1769 or 1770, and was as well known as old Mr. Moore, the father of one of your present inspectors. That celebrated farmer and statesman, Timothy Pickering, is perfectly correct in his conjecture about the origin of the name of Timothy Grass;[17] and there are many old Baltimorians, yet remaining, who will delight you with an account of the fine crops of Timothy cut and cured on the Meadow, which was attached to the old mill now in ruins. Charles Constable, lumber merchant, is now the oldest native of Baltimore. He can probably tell you all about the Hanson family."

Except for the discordant statements of his reputed wanderings this account of Timothy Hanson is the only one with circumstantial details that has been found.

In American genealogies two families by the name of Hanson are recorded; one from Kent Co., Maryland, having in it no one named Timothy, and one mentioned in Savage's Genealogical Dictionary of New England,[18] as follows:

[17] Pickering, Timothy, writing to the American Farmer (1: 390) from Wenham, Mass., Feb. 11, 1820, says:

"Mr. Southwick, the learned author of the Treatise on Agriculture, in Section XI, published in your paper No. 86, discoursing on grasses, mentions Timothy, and says that 'in Europe it is called Herd-grass, Cat's-tail, or Phleum pratense, its botanical name'; but as the plant is of Yankee origin, we have chosen to retain the Yankee denomination. Dr. Elliot of Conn. who in the last century wrote several essays on field-husbandry in his third essay, printed in 1751, says, 'There are two sorts of grass, which are natives of the country, which I should recommend; these are Herd-grass (known in Pennsylvania by the name of Timothy grass;) the other is fowl meadow, sometimes called Duck-grass, and sometimes Swamp-wire-grass. It is said that Herd-grass was first found in a swamp in Piscataqua (Portsmouth, N. H.) by one Herd, who propagated the same.' It is a fact that it is now known among farmers, generally in Massachusetts, and I believe throughout New England, only by the name of Herd's grass. From New England I have supposed that the seed was carried to Pennsylvania, and there, or in the three lower counties, now the state of Delaware, being cultivated by a person whose surname was Timothy, the grass received his name; and under that name, was sent from Philadelphia to England. In such English books on agriculture, as have fallen in my way, it is uniformly called Timothy, or cat's-tail."

[18] Savage's Genealogical Dictionary of New England, 2: 352.

"Hanson, Thomas, *Dover*, 1657,[19] freem. 5 June, 1661, prob. d. 1666, as his will was pro. 27 June, 1666. His wid. was K. by the Ind. His ch. were Tobias, Thomas, b. a. 1643; Isaac; *Timothy;* and two ds."

There is no further information about the Timothy Hanson spoken of in Savage's Genealogical Dictionary, though other members of the family are accounted for in that and other New England localities. It is of interest to note that this Timothy Hanson is from the same locality as Herd.

Quint[20] mentions a grant of land near Salmon Falls (N. H.) made to Thomas Hanson in 1658. There is sufficient corroborative evidence in his account to identify this Thomas Hanson with the one mentioned by Savage. According to Quint's statement, Thomas' son Timothy was not of age when his father's will was probated in 1666. Quint states that Thomas Hanson had a great-grandson named Timothy, and mentions an older brother of this Timothy who was born in 1702. This Timothy (who, according to Quint also had a son Timothy) might easily have been the one mentioned above as living in Baltimore about 1750 and introducing to the public what was there called "Timothy Hanson's Grass." On the other hand, if timothy was introduced into Maryland about 1720, the introduction might have been made by Timothy Hanson, son of the original Thomas Hanson mentioned by Savage. The 1720 date rests solely on the statement of Vasey published in 1884, unless Vasey had access to some account that has escaped our search. It should be remembered that timothy was well known according to Franklin in 1747.

The American origin of timothy as a cultivated crop seems scarcely to be doubted. In England it was a common grass in the fields known under the names of cat's-tail grass and meadow cat's-tail grass, but it was never cultivated nor considered valuable. Following its utilization in this country, it attracted interest in England through the mistaken idea that the grass so successful here was new there. Seed was sent to England prior to 1746 under the name St. Timothy grass.[21] According to the statement quoted below, it was again imported from Virginia in 1763.[22]

"Rocque has also cultivated another artificial grass called timothy-grass. This was in the beginning of the year 1763, brought over from Virginia by Mr. Wyche."

[19] Probably the date of the arrival of Thomas Hanson in America.

[20] Quint, Alonzo H., Genealogical Items Relating to Dover, N. H., in The New England Historical and Genealogical Register (published quarterly by the N. E. Hist. and Genealog. Soc.), Vol. VI, p. 329. 1852.

[21] Ellis, Wm., l. c.

[22] Annual Register for the Year 1765, l. c.

A letter from Mr. Rocque[23] to Mr. Corbet dated December 7, 1763, confirms the first part of the above statement. He says:

"As to Timothy-grass, it grows prodigiously quick. I have sowed it for the first time in September last."

Mr. Peter Wyche was chairman of the Committee on Agriculture of the London Society for the Encouragement of Arts, Manufacturers, and Commerce (now called Royal Society of Arts) about the year 1760. He died some time prior to November 15, 1763. There is no published evidence that he ever visited America. A search through the Memoirs of Agriculture by Dossie, the Museum Rusticum et Commerciale, and other publications connected with the Society of Arts, made with the hope of finding the record of Mr. Wyche's importation of timothy, was unsuccessful.

Stillingfleet[24] in a note dated September 14, 1763, on the gathering of meadow cats-tail seed says seed was brought from New England.

"This is what is called Timothy grass lately brought from New England, as I am assured by a skillful botanist who has raised it from the seed."

After a few years trial by English farmers it failed to meet with favor, as is shown by quotations below:

"Its reputation here was short-lived, and deservedly; for it has no one good property in which it is not excelled by the fox-tail grass; and besides this it is harsh, and late in its appearance. It is proper only for moist lands; in a dry soil it makes a pitiful appearance."—Thomas Martyn.[25]

"It is very productive but coarse and late, and has no excellence, that we are acquainted with which the Alopecurus pratensis does not possess in an equal degree."—Wm. Curtis.[26]

"As to the burnet, spurry and timothy grass, although their virtues have been highly celebrated by many authors, yet I believe they have never been found to answer in the cultivation in any degree equal to the sanguine commendations bestowed on them by these authors, or advocates."—John Banister, of Kent.[27]

Although Sir John Sinclair,[28] and others later made trials of timothy, it does not seem to have found a place in English agriculture except as a grass to use in mixtures.

In this country from the time Jared Eliot recommended the culture of "herd grass," and Benjamin Franklin called it "mere timothy,"

[23] Museum Rusticum et Commerciale, 1: 306. 1763.
[24] Coxe's edition of Stillingfleet's work, Observation on Grasses, p. 258. 1811.
[25] Martyn, Thomas, Flora Rustica, vol. 1. 1792.
[26] Curtis, Wm., British Grasses. 1798.
[27] Banister, John, A Synopsis of Husbandry. London, 1799.
[28] Sinclair, Sir John, Code of Agriculture. 1818.

the importance of timothy has increased until, even as early as the first part of the nineteenth century, it became the most important hay crop in the United States. A few references indicating this are given below in chronological order:

1775. "A large portion of every farm in New England consists of meadow and pasture land; * * * the common herbage * * * is a grass which has made much noise in England under the name of Timothy."—"American."[29]

1787. "They begin, however, to sow some quantity of herd's-grass seed, which they call Timothy." (He is speaking of a locality near Morristown, N. J.).—Cutler.[30]

1789. Queries and Answers on the present State of Agriculture in Delaware.
Q. What plants are cultivated * * * for cattle?
A. * * * More especially *timothy* and clover are cultivated for the use of cattle.—Tilton.[31]

1790. "More needs not to be said here of a grass the great value of which is so well known in New England."—Deane.[32]

1799. "The properties of Timothy need not be here mentioned, as the plant and its properties are very generally known in America."—Parkinson.[33]

1801. "Timothy grass is extensively cultivated in the middle and northern States of the American Union."—Strickland.[34]

1804. "Timothy grass * * * makes the best hay and the greatest quantity of any known at present in this country."—Roberts.[35]

1805. "Timothy * * * according to the accounts of travellers in America, it constitutes the principal support of cattle and other animals."—Dickson.[36]

1807. "Timothy grass, or phleum pratense, is more extensively cultivated than any other grass in the United States."—Mease.[37]

1818. "A well known and important grass, not a native, but *now completely naturalized* in this country."—Barton.[38]

1824. "This grass is extensively cultivated."—Bigelow.[39]

[29] American Husbandry, by an American (native of Sweden). 1: 57. London, 1775.

[30] Cutler, M., in Life, Journals and Correspondence. 1: 288. 1888.

[31] Tilton, James, in American Museum, 5: 276. 1789.

[32] Deane, Samuel, The New England Farmer; or Georgical Dictionary, p. 285. 1790.

[33] Parkinson, R., The Experienced Farmer, vol. 2, Supplement, p. 8. 1799.

[34] Strickland, Wm., Observations on the Agriculture of the United States, p. 63. London, 1801.

[35] Roberts, Job, The Pennsylvania Farmer, p. 49. 1804.

[36] Dickson, R. W., Practical Agriculture, 2: 833. London, 1805.

[37] Mease, James, Geological account of the United States, p. 225. 1807.

[38] Barton, Wm. P. C., Compendium Florae Philadelphicae, 1: 47. 1818.

[39] Bigelow, Jacob, Florula Bostoniensis, 2d edition, p. 28. 1824.

1827. "Till within a few years our farmers rarely sowed any grass seeds, but those of clover and herd's grass or timothy, as it is called in middle states."[40]

1846. "We are inclined to place timothy first in the list of grasses."—Allen.[41]

It is an interesting fact that almost as far back as there are publications relating to early American agriculture, timothy was used not only as a crop to sow alone, but in mixtures with other grasses and with red clover.

George Washington gives directions for its use in a letter written from Philadelphia to his overseers, July 14, 1793:[42]

"The lowest and wettest part thereof is to be sown with timothy seed alone. All the other parts of it are to be sown with timothy and clover seeds mixed. * * * Where clover and timothy seeds are mixed and sown together, allow five pints of the first and three of the latter to the acre; and where timothy alone is sown, allow four quarts to the acre."

There are also numerous other instances of its use in this way. Among them, the earliest are quoted:

"Herds-grass, as good and profitable as any. Grows well on any soil except sandy and gravelly, when mixed with clover, as that decreases, this increases, so that the crop of grass will hold out for several years—cut it just before it goes out of blossom, or a little sooner."—John Dabney.[43]

"It is not uncommon in the ordinary husbandry, to sow lots of ground with clover and timothy seeds mixed."—J. B. Bordley.[44]

"It is a common practice in Connecticut, to sow timothy and clover mixed."—Job Roberts.[45]

"Having sown the usual quantities of clover and herds-grass, I gave the whole a small dressing of yard manure."[46]

"The common practice of sowing clover and Herd's-grass in the spring, immediately after the sowing of the grain, is superior to that recommended by some European writers, of sowing them in the autumn after the grain crop is harvested. Clover and grass sown in the autumn, are in this climate, extremely apt to be 'winter killed.' * * *"[47]

One other point regarding the grass, namely, its nativity in America, is a question partly historical and partly botanical.

[40] Massachusetts Agricultural Repository and Journal, 10: 13. 1827.
[41] Allen, R. L., A Brief Compend of American Agriculture, p. 85. 1846.
[42] Published in The Farmers Cabinet, vol. 7, no. 7, Feb., 1843.
[43] Dabney, John, An Address to Farmers, p. 54. Salem, 1796.
[44] Bordley, J. B., Essays and Notes on Husbandry and Rural Affairs, 2d ed., p. 12. Philadelphia, 1801.
[45] Roberts, Job, The Pennsylvania Farmer, p. 149. Philadelphia, 1804.
[46] Memoirs, Agricultural Society of Massachusetts, 4: 165. 1816.
[47] Massachusetts Agricultural Repository and Journal, 5: 353. 1819.

Many of the early agricultural writers believed it to be native of America and this idea was held by so high an authority as Dr. Vasey.[48] He says:

"It is undoubtedly indigenous in the mountain regions of New England, New York and the Rocky Mountains."

From a historical standpoint it may suffice to point out that none of the early botanical explorers, with the exception of Cutler, mentions timothy, although it was in cultivation before the time of Kalm. Among these explorers are Cornuti, whose work on Canadian plants was published in 1635; Peter Kalm, who visited America in 1748 and 1749 and traveled throughout the Eastern States and northward into Canada; Clayton, who collected plants in Virginia, descriptions of which are published in Flora Virginica by J. Frederick Gronovius, 1743; Bartram, who traveled from Pennsylvania to Canada prior to 1751; Walter, who published his Flora Caroliniana in 1788; and Michaux, who collected throughout the Eastern States and Canada and published his "Flora Boreali-Americana" in 1803.

From the purely botanical standpoint the evidence that timothy is not native in North America would require an extended treatise, going into details of the different sorts of evidence by which such a conclusion is reached. It suffices to point out that every recent botanical writer in dealing with the subject has considered without question timothy to be an introduction from the Old World. So far as New England alone is concerned, and this region is of particular interest because timothy was probably first cultivated there, the testimony of Prof. M. L. Fernald of Harvard University, the highest authority on the New England flora, should have greatest weight. Prof. Fernald writes as follows:

"Gray Herbarium, Harvard University,
Cambridge, Massachusetts, U. S. A.

Prof. C. V. Piper,
Bureau of Plant Industry,
Washington, D. C.

Dear Prof. Piper:

I have just returned to Cambridge and find your letter in regard to *Phleum pratense*. I have never seen the slightest sign that *P. pratense* is native in New England or Eastern Canada. I have scoured the most primitive areas for years and have never come across the grass but once away from settlements. That was when a single specimen was found at a camp-site on Mt. Katahdin. . . . . .

[48] Vasey, George, U. S. Dept. Agr., Misc. Report No. 32, p. 63. 1884.

P. alpinum is the most abundant grass on some of the alpine tablelands of Eastern Quebec and is found less abundantly on the mountains of northern New England. The Herbarium gives no evidence that *P. pratense* is indigenous with us.

Sincerely yours,
(Signed) M. L. FERNALD."

The grass is mentioned either as herd's grass or timothy in all of the works cited below. In most cases the reference is such as to imply that the crop is well known. In those publications marked with an asterisk the grass is said to be native to America.

Year.	Publication.	What Called.
1747–59.*	Essays on New England Husbandry, by Jared Eliot (1760).	Herds grass. Timothy.
1764.	Memoirs of a Huguenot Family—Compiled from original autobiography of Rev. James Fontaine, etc., by Ann Maury, p. 443. 1853. (A letter in this publication dated Jan. 2, 1764, acknowledges the receipt of timothy-grass from Virginia.)	Timothy grass.
1775.	American Husbandry. By an American (native of Sweden). 1: 57. London.	Timothy grass.
1787.	Life, Journals and Correspondence of M. Cutler, 1: 288.	Herd's-grass. Timothy.
1788.	Columbian Magazine, 5: 503.	Timothy grass.
1789.	American Museum, 5: 276.	Timothy. Timothy grass.
1789.	Farmers Magazine, 1: 257.	Timothy. Timothy grass.
1790.*	New England Farmer; or Georgical Dictionary, by Samuel Deane (a second edition in 1797).	Timothy, Herd's-grass or Fox tail. Bulbous cat's tail.
1792.	Mr. Imlay, of New Jersey, in American Museum, 12: 265.	Timothy grass.
1793.*	The Practical Farmer, by John Spurrier, of Delaware (original American edition published at Wilmington).	Timothy grass.
1796.	An Address to Farmers, by John Dabney. Salem.	Herds-Grass.
1797.	Agricultural Enquiries on Plaister of Paris, by Richard Peters. Philadelphia.	Timothy-grass.
1797.	Tours into Kentucky and the Northwest Country. Three Journals by the Rev. James Smith of Powhatan Co., Va. 1783, 1795, and 1797. (Published in Ohio Archaeological and Historical Society Quarterly, vol. 16 (1907), p. 390.)	Timothy.
1799.	The Experienced Farmer, by R. Parkinson. Philadelphia.	Timothy.
1799.	Monthly Magazine and American Review, 1: 123.	Timothy.
1801.	Essays and Notes on Husbandry and Rural Affairs, by J. B. Bordley, 2d ed. Philadelphia.	Timothy.
1801.	Turnip & Peafallows, with a design of Rotation of Crops, Recommended to the Farmers and Planters of the United	Timothy.

	States of America. By Richard Parkinson, p. 8. Washington City.	
1803.	A Treatise on Practical Farming. By John A. Binns, of Loudon Co., Virginia.	Timothy.
1804.*	Willrich, Domestic Encyclopaedia, 3: 195. First American edition edited by James Mease.	Timothy.
1804.*	The Pennsylvania Farmer, by Job Roberts. Philadelphia.	Timothy.
1806.	Memoirs Agricultural Society of Massachusetts, vol. 4, 1816. (Letter from a man from Brookfield, Oct. 15, 1806.)	Herds-grass.
1807.	Geological Account of the United States, by James Mease.	Timothy grass; Cat's tail grass of England.
1814.	Philadelphia Society for the Promotion of Agriculture. Memoirs, 3: 330.	Timothy.
1818.	Philadelphia Society for the Promotion of Agriculture. Memoirs, 4: 156.	Timothy.
1818.	Compendium Florae Philadelphicae: Containing a Description of the Indigenous and Naturalized Plants found within a circuit of ten miles around Philadelphia. By William P. C. Barton. Vol. I. Philadelphia.	Timothy-grass.
1819.	Massachusetts Agricultural Repository and Journal, 5: 353.	Herd's-grass.
1820.*	The Farmer's Assistant, by J. Nicholson. Philadelphia.	Meadow-Cats-tail; Timothy grass; Herds-grass; (It is erroneously called Foxtail.)
1820.	The American Farmer, 1: 390. Timothy Pickering, writing from Wenham, Mass., Feb., 1820.	Timothy; Herd-grass; Herd's-grass; Cats-tail.
1826.	The Farmer's Library, by L. Lathrop, of Vermont. (Windsor.)	Meadow Cats Tail; Timothy grass; Herds Grass. (Erroneously called fox tail.)
1841.	Farmer's Cabinet, 5: 179.	Timothy.
1846.	Allen's American Agriculture, p. 85.	Timothy; Cat's tail; Herd's grass.

Summary.

From the data above quoted the important historical statements may be summarized as follows:

1. According to the statements of Jared Eliot, first published in 1747, timothy was first "found in a swamp in Piscataqua by one Herd, who propagated the same."

2. Benjamin Franklin in 1747 refers to the grass in Pennsylvania as "mere timothy."

3. Timothy seed was taken to England from America as early as 1746. The later importation of seed into England by Mr. Peter

Wyche, often referred to by writers, was according to contemporary evidence in 1763.

4. The name timothy is said by various English writers in 1764 and shortly thereafter, to be derived from one Timothy Hanson. Regarding the identity of this man and his relation to the dissemination of the grass, the evidence is very conflicting. The most circumstantial account makes him a resident of Baltimore, though the same writer expresses the belief that Mr. Hanson was a native of one of the New England States.

ON OSMOSIS IN SOILS.[1]

C. J. Lynde and J. V. Dupré,
Macdonald College, P. Q., Canada.

For the sake of clearness we have divided this paper into three parts, as follows:

I. A historical statement of our previous work on the osmosis of soils.

II. Experiments in which we measured the osmotic pressures which were obtained when a column of very fine soil was used as a semi-permeable membrane and a concentrated soil solution as the active solution.

III. An experiment to determine whether or not the pressures observed were due simply to the swelling of the soil column.

I. Historical.

It is usually stated that soil water is subject to three types of movement, namely, gravitational, capillary and thermal. In studying the movement of soil moisture the senior author was gradually led to the conclusion that in producing this movement there is some agency at work, other than those just stated. In considering what this agency might be he was led to the following theory.

Theory that Soils Act as Semi-Permeable Membranes.

It is possible (1) that soils act as semi-permeable membranes; (2) that the greater the depth of the soil the greater is its efficiency as a semi-permeable membrane; (3) that a soil solution moves through the soil by osmotic pressure from points where the solution is less concentrated to points where it is more concentrated.

In 1912 the senior author read two papers[2] before the American Society of Agronomy at their meeting at Lansing, Mich. The results presented indicated that the above theory is true for a heavy clay

[1] Read before the Royal Society of Canada, May 27, 1914.

[2] Lynde, C. J., Osmosis in Soils: Soils Act as Semi-Permeable Membranes, Proc. Amer. Soc. Agron., 4: 102–108. 1912. Also in Journal of Physical Chemistry, 16: 759. December, 1912.

Lynde, C. J., and Bates, F. W., Further Studies in the Osmosis of Soils, Proc. Amer. Soc. Agron., 4: 108–121.

subsoil. It acts as a semi-permeable membrane, its efficiency as a semi-permeable membrane increases with its depth, and the soil moisture moves through the soil membrane from points of less concentration to points of greater concentration.

Last year he had the honor of reading a paper[3] before this society in which he gave some results obtained by using the soil constituents as semi-permeable membranes. In the mechanical analysis of soils, the soils are divided into grades according to the size of soil particles. The grades are known as sands, silt and clay. These are the soil constituents. We found that the smaller the soil particles in a soil constituent the greater is the efficiency of the constituent as a semi-permeable membrane.

In the papers read in 1912 the greatest osmotic pressure recorded was 5.6 grams per square centimeter. This corresponds to a water column about 2 inches high. In the paper read before this society last year the greatest osmotic pressure recorded was 42.5 grams per square centimeter, corresponding to a water column about 16 inches high. This year we have carried this further and we have obtained, as is shown below, an osmotic pressure of 352 grams per square centimeter, corresponding to a water column of over 11.5 feet.

II. On the Osmotic Pressure Obtained by Using a Column of Very Fine Soil as a Semi-Permeable Membrane, and a Concentrated Soil Solution as the Active Solution.

A loam soil which was known to contain a considerable amount of very fine soil was used. The loam was soaked in bulk over night in a pan of distilled water. From this mud eight shaker bottles were loaded each with approximately 5 g. of soil, 150 c.c. distilled water and 5 drops of ammonia.

After one hour in the shaker the bottles were allowed to stand for 15 minutes and the liquid was decanted into an enameled pan which was then placed in an oven at 110° C. A further 150 c.c. of distilled water was then added to each bottle and the bottles were again shaken for one hour. After standing for 15 minutes the liquid was again decanted and added to the liquid obtained from the first shaking. To sterilize the liquid and free it from ammonia it was brought to about 100° C. in the oven and then placed over a burner until decided

[3] Lynde, C. J., and Dupré, H. A., Osmosis in Soils: The efficiency of the Soil Constituents as Semi-Permeable Membranes, Journal Amer. Soc. Agron., 5: 102–106. 1913. Also in Transactions of the Royal Society of Canada, Third Series, Vol. VII, 1913.

ebullition took place. The liquid was allowed to cool over night and was then decanted into a 2,000 c.c. cylinder. It was allowed to settle in the cylinder for seven days.

A cylinder was filled with liquid in a similar manner each day for seven days. After seven days the liquid in the first cylinder was decanted from the sediment and evaporated down in an enameled pan in an oven at 110° C. Next day the liquid from the second cylinder was added to this pan. This was continued each day for seven days. The liquid was finally evaporated down until it was a rather thick syrup.

How the Apparatus Was Set Up.

The apparatus used is shown in figure 1. Two glass tubes approximately 15 cm. long and 1 cm. in diameter were closed at one end with one layer of cotton cloth. They were then filled with the thick hot liquid and placed in cups of the centrifuge. The cups were filled with hot distilled water to the level of the liquid in the tubes. The centrifuge was run at top speed for 15 to 30 minutes; the liquid was then decanted from the sediment and replaced by fresh thick liquid. This was continued until the sediment reached the desired thickness or until the thick liquid was exhausted. The centrifuge made 1,300 r.p.m. and the center of the column of sediment in each tube was 25 centimeters from the center of the axes of the centrifuge. The liquid remaining in the tubes after the last settling was used as the soil solution.

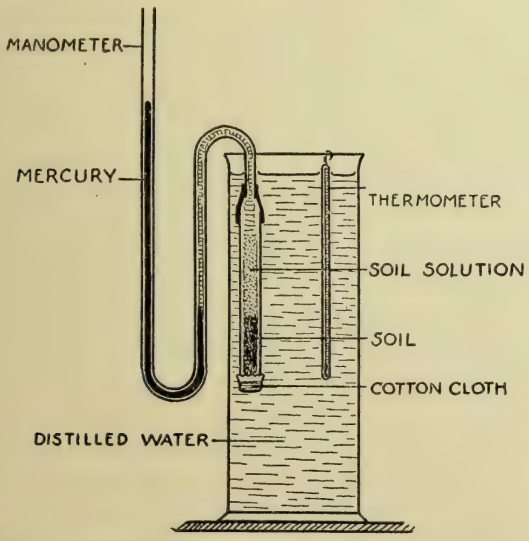

FIG. 1.—Apparatus used in measuring osmosis in soils.

An open arm mercury manometer was then attached to each tube and the tubes were placed in distilled water. After the observations on the pressure had been completed, the electrical resistance of the soil solutions was compared to that of a .02N KCl solution.

We made two separate experiments and repeated the second experiment twice, using the same soil and solution as in the second experiment. The results obtained are shown in Table 1.

TABLE 1.—*The Osmotic Pressure Observed in the Various Experiments.*

No. of Experiment.	No. of Tube.	Osmotic Pressure.		
		Hg.	H_2O.	H_2O.
		cm.	*cm.*	*feet*
First[1]	1	15.5	210.8	6.9
Do.	2	23.8	323.7	10.6
Second[2]	1	25.9	352.2	11.5
Do.	2	lost		
Second repeated,[3] first trial		17.0	231.2	7.6
Second repeated, second trial		20.3	276.1	9.0

[1] Duration of experiment, 14 days. Depth of soil column, 1, 7 cm.; 2, 4 cm. Resistance of soil solutions compared to .02N KCl solution, soil solution 70 ohms, .02N KCl solution 270 ohms, at 18° C.

[2] Duration of experiment, 6 days. Depth of soil column, approximately 6 cm. Electrical resistance of soil solution, 60 ohms; of 02N KCl solution 270 ohms, at 18° C.

[3] Duration of first trial three days, at the end of which time the manometer was accidentally broken. It was replaced and the experiment started again. Duration of second trial ten days.

III. An Experiment to Determine Whether or Not the Pressure Observed is Due to Swelling of the Soil Column.

It occurred to us that the pressures we observed might be due to the swelling of the soil column. To settle this point we prepared soil as above, allowing it to settle in water for 4 days. We then set up two tubes as usual and measured the pressure developed. We also set up a third tube in the same way except that we inserted a solid rubber stopper instead of the layer of cotton cloth. Thus no movement of moisture due to osmotic pressure could occur. If then we observed a pressure it could not be due to osmotic pressure but must be due to some other cause such as the swelling of the soil column.

The two tubes set up in the ordinary way developed osmotic pressures, but less than those given above.

The third tube with the solid rubber stopper not only did not develop any pressure but gave a negative pressure. This indicates that the soil solution is absorbed and that the total volume of soil plus solution decreases.

We then poured the soil solution out of the tube with the rubber stopper and added distilled water. Again a negative reading was obtained and much greater than with the soil solution. This indicates that the soil column absorbs water more readily than it absorbs soil solution and that there is a greater decrease in total volume. The results of this experiment are shown in Table 2.

TABLE 2.—*The Osmotic Pressures Observed in Tubes 1 and 2 and the Negative Pressures Observed in Tube 3.*[1]

Tube.	Pressure, Hg.	Time.
	cm.	*days*
1	8	15
2	9.1	15
3 with soil solution	— 3.7	8
3 with distilled water	—10.3	15

[1] Depth of soil columns: 1, 7.5 cm.; 2, 8.5 cm.; 3, 5.5 cm. Electrical resistance of soil solution: 1, 70 ohms; 2, 85 ohms; 3, 80 ohms; of .02N KCl solution, 270 ohms at 18° C.

CONCLUSIONS.

I. Using a concentrated soil solution as solution and a column of soil approximately 2.5 inches deep as semi-permeable membrane we have observed an osmotic pressure equal to the pressure exerted by a column of water 11.5 feet high.

II. The results indicate that the pressures observed are not due to the swelling of the soil column.

They indicate also that the pressures observed are due to osmosis, as follows: (*a*) the semi-permeable membranes used in investigations on osmotic pressure are colloids; (*b*) there is strong evidence that the action of semi-permeable membranes is one of unequal absorption. One liquid is absorbed more readily than the other and the movement is toward the liquid least absorbed. The soil we have been using as a semi-permeable membrane resembles the ordinary semi-permeable membranes in both ways: (*a*) it is quite probable that it is in a colloidal state; (*b*) it absorbs water more readily than it does a soil solution and the movement is toward the liquid least absorbed, namely, toward the soil solution.

GRAIN CROP MIXTURES.[1]

C. W. WARBURTON,

OFFICE OF CEREAL INVESTIGATIONS, U. S. DEPARTMENT OF AGRICULTURE.

In nature, plant associations are the usual thing, plant segregations the exceptional, though there are of course areas which are covered with a single species of plant to the virtual exclusion of all others. In agriculture, except in the production of forage, partial or complete segregation rather than crop association is the rule or at least the intention, for the plants which appear in association with our corn or wheat or cotton quite commonly are there contrary to the desire rather than at the volition of the grower. We call them weeds. Crop associations, however, are much more common than appears at first glance. In addition to the numerous crop mixtures of grasses and legumes, one might mention such common associations as corn and cowpeas, the small grains with the grasses and clovers, and mixtures of the various cereals. These crop associations, it seems to me, fall naturally into three classes.

THE THREE CLASSES OF CROP ASSOCIATIONS.

1. *Mixed Crops or Crop Mixtures.*—In actual crop mixtures, the components are grown together during all or practically all the life of the crops and are harvested together. They may or may not be sown together. To this class belong most of the forage mixtures, such as timothy and clover, corn and cowpeas or sorghum and cowpeas for hay or silage, oats and peas, rye and vetch, and the like. Here also belong the cereal crop mixtures, such as oats and barley, oats and wheat, wheat and flax, and winter oats and rye. The cereals and field peas are also grown together for the production of grain. Obviously, mixed crops may be made up of two, three or more components.

2. *Companion Crops.*—When two or more crops are grown together on the same field but are not sown or harvested together, though the life of the crops is practically the same, they may well be called companion crops. A good example of this class is the growing of cotton

[1] Read before the Washington (D. C.) Section of the American Society of Agronomy, Jan. 20, 1915.

and cowpeas in alternate rows, as is often practiced in the South. Similarly, this class of associations includes the growing of cowpeas or soy beans with corn, whether in alternate rows or when the legume is sown between the rows at the last cultivation, for the crops are neither sown nor harvested together. The combination of corn and pumpkins so common throughout the Northern States and the Brazilian custom of growing corn and rice together as described by Dorsett[2] are other examples of companion crops.

3. *Tandem Crops.*[3]—In this class of association, the crops are grown together only during a part of the life of one or both and they are not harvested together. The most familiar example, perhaps, of tandem crop association is the growing of a cereal with a biennial or perennial forage crop or crop combination, such as timothy and clover. Here, the two crops may be sown at the same or at different times (an example of the latter is the sowing of clover seed in late winter or early spring on fields of fall-sown grain), but most of the growth of the second crop in the tandem is made after the first crop is harvested. Other examples of such combinations are afforded by the practice of sowing some winter annual, biennial or perennial in corn at the last cultivation, as crimson clover, winter wheat, or timothy and clover; the sowing of vetch, bur clover or crimson clover in cotton fields; and rape with wheat, oats, or barley. An odd combination recently reported by an Austrian investigator[4] is that of wheat and carrots. Another is the Algerian one described by Fairchild[5] of alfalfa in rows with wheat between the rows.

A peculiar phase of tandem cropping which might perhaps be called relay cropping is found in the Southern States. Two examples of this phase are the combinations of Bermuda grass and bur clover and of oats and Johnson grass. Bermuda grass makes its growth only in warm weather, starting late in spring and being killed by the first frost of fall. Bur clover, on the other hand, is a winter annual, starting with the approach of cool weather in the fall, growing through the winter, producing seed and dying soon after Bermuda grass begins to grow in the spring. Thus in the South, particularly on certain soils, a pure Bermuda grass lawn or pasture in the summer may show an equally pure stand of bur clover in the winter. It is not an un-

[2] Dorsett, P. H., in an unpublished paper presented at the Washington (D. C.) Section of the American Society of Agronomy, Dec. 18, 1914.

[3] For the suggestion of this term the writer is indebted to Mr. C. R. Ball.

[4] Grabner, E., Weiner Landw. Ztg., 64 (1914), No. 23, pp. 208–209. Noted in Exp. Sta. Record, 31: 735.

[5] Fairchild, D. G., Cultivation of Wheat in Permanent Alfalfa Fields, U. S. Dept. of Agr., Bur. Plant Indus. Bul. No. 72: 5–7. 1905.

common practice in some parts of the South to sow oats on Johnson grass meadows which have been disked or shallow plowed, harvest a crop of oats and then get one or two crops of Johnson grass hay later in the season from the same field, perhaps repeating the same process the following year. The Johnson grass and bur clover relay is also practiced.

Grain Crops Grown in Mixtures.

The growing of crops in associations is an old custom, just how old I can not say. It seems to be followed pretty generally over the world, but perhaps reaches its highest development (if the making of queer mixtures may be so termed) in India. The growing of grain crops in mixtures is practiced to some extent in Europe, though the area devoted to mixed grains appears to be decreasing. In America, mixed grain crops are rather common in eastern Canada, particularly in Ontario, and much less common in our Northern States.

The area devoted to mixed grains in 1914 in all Canada is estimated as about 475,000 acres, as compared with about 1,500,000 acres in barley for the same year. In Ontario alone, the area in mixed grains in 1914 is estimated at 344,000 acres, while the acreage in barley is estimated at 461,000 acres. The acreage in oats is of course very much larger. No figures are available on the acreage sown to mixed grains in the United States, but it is very small in comparison with that of any of our leading cereals when sown alone. Bailey[6] states that "Wheat and oats are frequently grown in mixtures through this section of the northwest (Minnesota), such mixtures being commonly known as 'succotash.'" Evans[7] has reported the sowing of flax with winter wheat, but this was on fields where the wheat had partially winter killed and the flax was sown in the spring to more fully occupy the land, so that the association was not a mixture in the sense in which the term is here used. Other mixtures which are grown in a limited way for the production of grain are those of barley and oats, spring wheat and flax, and winter oats and rye.

The principal reason for growing grain crops in mixtures is for the increase in yield which may be produced. The growing of oats or barley with peas (for under certain conditions peas must be considered a grain crop) helps to keep the peas more erect and makes the crop easier to harvest. Just why a mixture of barley and oats, for instance, is quite likely to yield more pounds of grain to the acre than either

[6] Bailey, C. H., The Composition and Quality of Wheat Grown in Mixtures with Oats, Jour. Am. Soc. Agron., 6: 215. 1914.

[7] Evans, M. W., Sowing Flax in Winterkilled Wheat Fields, U. S. Dept. Agr., Bur. Plant Indus. Circ. No. 114: 3–7. 1913.

crop when sown alone is hard to say. With associations of a legume and non-legume, the additional growth may be due wholly or in part to the supply of nitrogen placed at the disposal of the non-legume by the legume. Lyon and Bizzell[8] have shown that under certain conditions there appears to be a mutual stimulation and added growth of plants in mixtures, whether or not one is a legume. Kaserer,[9] an Austrian, states that the development of the roots of plants in mixtures is quite different from that of the roots of the same plants in pure cultures, the surface soil being much more completely filled with roots in the mixtures.

Experiments in the United States.

The experiments with mixtures of grain crops within the limits of the United States are remarkably few in number. Those which have been made were not continued long enough or were not made with the right mixtures to obtain the best results, but a review of them should be of interest.

Morrow and Hunt[10] tested various mixtures of oats and spring wheat at the Illinois station in 1889 and 1890, in comparison with 2½ bushels of oats sown alone and with 2 bushels of wheat alone. To quote from their statement:

> "It is the practice of some farmers in a limited way to sow oats and spring wheat together. * * * It has been claimed that spring wheat of good quality has been raised in this way, while when sown alone it was more or less a failure. The total yield of grain is said to be greater."

In 1889, the wheat crop was almost a failure, but weather conditions were more favorable for wheat in 1890 and a better yield was produced. In 1889, only one of the mixtures exceeded in yield the average of two plats sown to oats alone, while the average yield of the six mixtures was at the rate of 1,140 pounds of grain as compared with 1,300 pounds to the acre of oats alone. In 1890, three of the six mixtures yielded more and three yielded less than the oats sown separately; the average of all the mixtures was 840 pounds and of the oats alone 820 pounds. For the two years, the mixtures in which ½ bushel of wheat was sown with 2 bushels and with 2½ bushels of oats yielded practically the same as 2½ bushels of oats alone; all the other

[8] Lyon, T. Lyttleton, and Bizzell, J. A., Is there a Mutual Stimulation of Plants Through Root Influence?, Jour. Am. Soc. Agron., 5: 38–44. 1913.

[9] Kaserer, H., Ztschr. Landw. Versuchsw. Osterr., 14 (1911), No. 8. Noted in Exp. Sta. Record, 26: 129.

[10] Morrow, George E., and Hunt, Thomas F., Field Experiments with Oats, 1890, Univ. of Ill. Agr. Exp. Sta. Bul. No. 12: 358–360. 1890.

mixtures fell considerably below the oats in yield. Morrow and Hunt concluded that there was no advantage in sowing spring wheat with oats. It may be noted, however, that spring wheat is not well adapted to central Illinois.

Hays[11] conducted an experiment with oats and wheat mixtures at the Minnesota station in 1891, comparing 4 mixtures of varying proportions with two rates of seeding for oats and two for wheat. The average yield from the oats alone was 2,914 pounds to the acre; from the mixtures, 2,902 pounds; and from the wheat, 2,331 pounds. The highest yield, however, was from a mixture sown at the rate of 2½ bushels of oats and ½ bushel of wheat to the acre. This plat yielded at the rate of 3,196 pounds of grain to the acre, while the highest yield of oats alone was 3,109 pounds and of wheat alone, 2,463 pounds. The third highest yield, 3,060 pounds, was from a mixture sown at the rate of 2¼ bushels of oats and ¾ bushel of wheat.

Atkinson, at the Iowa station, grew mixtures of White Russian oats and Bluestem wheat for two years (1899, 1900), in comparison with each variety sown separately. In every case, his rate of seeding was 8 pecks to the acre, thus combining 4, 5, 6 and 7 pecks of oats with 4, 3, 2 and 1 pecks of wheat respectively. For the two years, the highest average production was 1,860 pounds, this being from a mixture of 4 pecks of oats and 4 pecks of wheat. All the mixtures yielded better than either grain sown separately, the average yield of wheat alone being 1,420 pounds and of oats alone, 1,205 pounds. Of this experiment Atkinson[12] says:

"So large an increase as the above could not always be expected by mixing grain, but the fact is established that larger returns may be obtained from a mixed crop than when each grain is seeded separately. In this case the increase can be accounted for by the crop standing better and rusting less when the oats and wheat were mixed."

Balentine[13] of the Maine station reports the results of a single year's test conducted in duplicate on plats of about ¼ acre each, in which a mixture of equal parts by weight of wheat and oats sown at the rate of 64 pounds to the acre was compared with 48 pounds of oats sown alone and with 96 pounds of wheat alone. The two plats of oats produced at the rate of 1,946 pounds of grain to the acre, those sown to the mixture 1,814 pounds and those to wheat 1,410 pounds. The yield of straw from the mixture was slightly more than from either crop alone. Balentine says:

[11] Hays, W. M., Grain and Forage Crops, Minn. Exp. Sta. Bul. 40: 276, 277. Dec., 1894.

[12] Atkinson, James, Field Crop Experiments, Iowa Sta. Bul. 45: 220. 1900.

[13] Balentine, W., Maine State Coll. Exp. Sta. Ann. Report for 1891, p. 144–5.

"The trial is decidedly in favor of oats separately as compared with oats and wheat mixed, and oats and wheat mixed, as compared with wheat alone.

"These results are in opposition to the teachings of many of our best farmers.

"The conclusion of the writer is that the crop that yields the larger number of pounds per acre when grown alone will not be benefited by mixing with a crop that produces a less number of pounds to the acre."

This conclusion seems to be well founded when there is a wide disparity in the yields of the two crops when sown separately, as was true in this instance.

Canadian Experiments.

The great mass of American data on grain crop mixtures is to be gleaned from the reports of the experimental farms maintained by the Dominion of Canada and from the reports of the Ontario Agricultural College Experiment Farm, particularly the latter. A few experiments with mixed grains have been conducted on the Central Experimental Farm at Ottawa, Ontario, but the tests made by Professor Zavitz at Guelph have been most complete and convincing. Tests have also been made at some of the branch experiment farms, as at Nappan, N. S., Brandon, Man., and Agazziz, B. C., but most of these have been for one year only, so that they will not be discussed here.

At Ottawa, Grisdale[14] conducted tests of several grain mixtures on field plats of one to two acres each for five years, 1900–1904. This test included peas alone, barley alone, and oats alone, in comparison with mixtures of peas and oats; oats and barley; barley, oats and peas; and wheat, barley, oats and peas. By far the largest yield, 3,751 pounds to the acre, was obtained from oats alone; the mixture of oats and barley ranked second, and barley alone, third.

In a later test for three years (1904–1906), Saunders[15] compared mixtures of wheat and oats, wheat and barley, oats and emmer, and oats and barley. He did not, however, report the yields of the various crops when grown separately. For the three years, the highest yields were produced by two mixtures of oats and barley, 2,360 and 2,347 pounds to the acre.

The first experiment with grain crop mixtures reported by Zavitz was begun in 1893 and continued for six years. In this experiment, all the possible combinations of oats, barley, wheat and peas were compared, as follows: Oats and barley; oats and wheat; oats and peas;

[14] Grisdale, J. H., Canadian Exp. Farms Reports, 1900, p. 84; 1901, p. 301; 1902, p. 84; 1903, p. 82; 1904, p. 98.

[15] Saunders, C. E., Canadian Exp. Farms Reports, 1904, p. 275; 1905, p. 225; and 1906, p. 251.

barley and wheat; wheat and peas; barley and peas; oats, barley and wheat; oats, barley and peas; oats, wheat and peas; barley, wheat and peas; and oats, barley, wheat and peas. For the six years, the average yield from a mixture of oats and barley was 2,261 pounds of

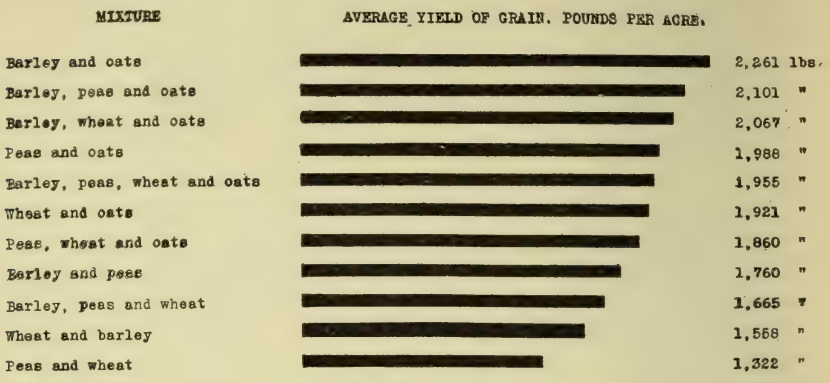

FIG. 2.—Graph showing average yield in pounds per acre obtained in a six-year test of various mixtures of grain crops at the Ontario Experiment Farm, 1893–1898.

grain to the acre; of oats, barley and peas, 2,101 pounds; and of oats, barley and wheat, 2,067 pounds. The yields from the other combinations ranged from these figures down to 1,322 pounds to the acre from the mixture of peas and wheat, as shown in figure 2. The yields of the different grains grown separately is not stated, but on this point Professor Zavitz[16] says:

"When a comparison is made between the different grains grown separately and the same grains grown in mixtures, it is found, in about 90 percent of the experiments, that the mixtures produced a larger yield per acre than the same grains grown separately."

Having determined that the largest yield was obtained from a mixture of barley and oats, Zavitz began experiments to show at what rates these grains should be sown. In the first of these tests, nine different rates of seeding were tried. One-half bushel of oats was sown in mixture with ½, 1 and 1½ bushels of barley, 1 bushel of oats with ½, 1 and 1½ bushels of barley and 1½ bushels of oats with ½, 1 and 1½ bushels of barley. Zavitz[17] summarizes the results as follows:

"The experiment has been conducted for six years in succession. The average results show that the greatest number of pounds of grain per acre was

[16] Zavitz, C. A., Ontario Agr. Coll. and Exp. Farm Ann. Rept., 23: 178. 1897. 179.

[17] Zavitz, C. A., Ontario Agr. Coll. and Exp. Farm Ann. Rept., 31: 178. 1905.

produced from a mixture of 1 bushel of oats (34 lbs.) and 1 bushel of barley (48 lbs.) per acre, or a total amount of 82 pounds of mixed seed per acre."

In a later test, conducted for the five years from 1907 to 1911, in which 3, 4 and 5 pecks of oats were sown in each of the nine possible combinations with 3, 4 and 5 pecks of barley (i. e., 3 with 3, 4 and 5; 4 with 3, 4 and 5; and 5 with 3, 4 and 5), similar results were obtained. The highest average yield, 2,059 pounds to the acre, was produced from the mixture of 4 pecks of oats and 4 pecks of barley and the next highest from the two mixtures that most nearly approximated that rate, 3 pecks of oats with 5 pecks of barley and 5 pecks of oats with 3 pecks of barley. Of these two tests, Zavitz says:

"An exceedingly interesting feature of the two experiments in which nine different proportions of oats and barley were used in combination, is the fact that the same mixture that gave the highest results in the first test of six years also gave the highest results in the other experiment of five years, the mixture being four pecks of oats (34 lbs.) and four pecks of barley (48 lbs.) or a total of 82 pounds of the mixture to the acre."[18]

Professor Zavitz was apparently not entirely satisfied that in oats and barley he had obtained the combination which produced the maximum yield of grain, for in 1902 he began a series of experiments in which a mixture of 1 bushel of oats and 1½ bushels of barley were compared with the same mixture to which ½ bushel of some other grain had been added. The other grains which were added to the mixture in this way were durum wheat, emmer, flax, and hull-less barley. The combination of oats and barley yielded more, in a five-year test, than any of the mixtures to which some other grain was added.

Having determined the kinds of grain to grow in combination and the rate of seeding which gave the best results, he attacked the problem of determining the best varieties of each grain to use in the mixture. To quote Professor Zavitz again:

"If barley and oats are grown together, it is, of course, important to secure those varieties that will mature about the same time. In order to do this, it is necessary to use a very early variety of oats with an ordinary ripening barley, or a very late variety of barley with an oat which matures at an average date. Of all the varieties which we have used in combination, we have found that the Early Daubeney oats and Mandscheuri barley make a very excellent combination. Another mixture which has given very good satisfaction is the Siberian or Banner oats and the Chevalier two-rowed barley."[19]

Still another elaborate experiment with grain mixtures was begun by Zavitz in 1907 and continued for five years. Previous tests had

[18] Ontario Agr. Coll. and Exp. Farm Ann. Rept., 37: 188. 1911 (1912).
[19] Ontario Agr. Coll. and Exp. Farm Ann. Rept., 31: 179, 180. 1905.

convinced him that the presence of barley in the mixture was essential if the largest yields were to be obtained, so every one of the nineteen mixtures included barley and in thirteen of them the Manchuria barley was used. One bushel of each crop was sown to the acre, the combinations all being of two kinds of grain only. The 13 mixtures with Manchuria barley included 5 varieties of oats, black hull-less and white hull-less barley, rye, emmer, durum wheat, flax and 2 varieties of field peas. The largest yield for the five years was produced from the mixture of Manchuria barley and Alaska oats, 2,436 pounds to the acre; the second highest from Manchuria barley and Daubeney oats, and the third from Manchuria barley and flax. The lowest yield, 1,940 pounds to the acre, was from the mixture of Black Hull-less barley and common emmer. In every case, barley made up more than 50 per cent of the crop produced, the range being from 52.86 per cent in the mixture of Himalaya (Guy Mayle) Hull-less barley and Siberian oats to 91.98 per cent in the mixture of Manchuria barley and flax. In the mixtures of oats and Manchuria barley, the percentage of barley, which was slightly less than 60 in the original mixture, ranged from 67.78 to 74.87 in the resulting crop.

Conclusions.

From these numerous experiments, it seems that a few general principles may be deduced. These are: (1) Grain crop mixtures may be expected to yield more than the grains composing them, if there is only a slight difference in the yield of the components when grown separately, but if the components differ considerably in yield the product of the mixture is likely to be intermediate between them. (2) The rate of seeding for the mixture should not be materially, if any, greater than for the components when sown separately. (3) Obviously, the highest-yielding varieties which will mature at the same time should be chosen.

Whether or not the farmer can afford to grow grain crop mixtures rather than some one or more of the grains separately will depend on how large an increase in yield may be expected from the mixture; on whether the mixture can be used as satisfactorily or economically for feed as the components separately; on the salability of the mixture as feed grain; and on the cost of separation, if separation is necessary. For instance, the growing of oats and wheat in mixture would be unprofitable if the increase in yield over the mean yield of the two crops was not large enough to more than pay the cost of separation. Further, it would be unwise to grow barley and oats together if the

crop could not be fed or sold profitably as feed grain, for the separation of oats and barley is difficult. There seem to be enough advantages to the practice of growing grains in mixture, however, to make it desirable for some of our northern stations to undertake some experiments with grain mixtures, especially mixtures of oats and barley.

BRIEFER ARTICLES.

ON NAMING VARIETIES.

E. G. Montgomery.

(Read before the American Society of Agronomy, November 9, 1914.)

In connection with the wheat survey made in New York the past summer, some interesting matters have come up in regard to the fate of variety names in the hands of the public.

One very interesting case was found in western New York, where we frequently found that "No. 6" was attached to the name of what we took to be at first several different varieties of wheat. For example, there was "No. 6," "International No. 6," "Rochester No. 6," "Clawson's No. 6," "Michigan No. 6," "Rural New Yorker No. 6," and "No. 16." Head samples were collected of all these varieties for comparison and they appeared to be the same thing, which led us to believe that this long list of names had a common origin. A little investigation suggested, at least, how some of the names arose. For example, it was found that about thirty years ago the International Seed Company, of Rochester, N. Y., had put out a variety called "No. 6." This would account for the first three names on the list. It is not as clear how the other names came into existence, but probably in the case of "Michigan No. 6" the wheat might have been sold in Michigan and then brought back from that State by some farmer. Clawson's No. 6 is probably the correct name, as Garrett Clawson put several varieties on the market. At any rate, we have evidence that the old name "No. 6" or "International No. 6," as I believe it was called at first, has been construed in a number of ways.

This brings up the question of whether it would not be desirable to take some steps for straightening out the nomenclature of our farm crops. I referred to this matter at the Columbus meetings of this Society as a result of some studies with a collection of oat samples secured principally from the seedsmen and experiment stations of the

country. More than 400 named varieties of oats were secured but it was found that even at the experiment stations they were sometimes calling different varieties by the same name. It would seem that the time is at hand when if we are to attach any importance to names of varieties, at least some effort should be made to establish a standard naming system. This, I think, is of especial importance now, when so many of our experiment stations are beginning to put out new selections of old standard types and have very often used a number system, such as "Minnesota No. 23" or "Wisconsin No. 10" to designate a new strain. One question which should be discussed at this time is whether the number system or naming system is the safest. Not only are numbers in danger of being attached to various common names as more and more new varieties come out from the different experiment stations under numbers, but as these new selections begin to cross State lines, it seems to me in time there will be considerable confusion.

If an official register of varieties could be started and maintained it would serve a useful purpose. This register might be on the plan of the herd books put out by the various live stock breeders' associations. If all the named varieties could be associated in such a book with some description as to their character, adaptation and whatever history we have regarding their origin, it would be of great service. How little most of us know about the origin of our common varieties of farm crops. For example, those who have been in agronomic work for twelve or fifteen years can recall when Swedish Select oats or Kherson oats were introduced, but how many young men who have come into the field in the last five years know anything about Swedish Select or Kherson, how or when they were introduced, or know how to find this out. If we had something on our shelves compared with the herd book, it would be possible when we wanted to secure information about a particular variety, to take down the book and turn to what is known about it, and would certainly be a useful and valuable source of information. This would also serve to keep history straight regarding the new selected strains being put out by the plant breeders. For example, I doubt if many would know the origin of Wisconsin No. 10 oats or Minnesota No. 23 corn. It would be useful if this could be put in a permanent record so that we might know that in the one case it is a selection of Swedish Select and in the other case a selection of White Cap corn. I simply cite these as examples. Most of us have not time to trace out information of this kind even though it is of importance, but would make use of it if it was easily and readily available, as it should be. I do not know where such a registry

ought to be started, but perhaps it could be taken on as a part of the work of the American Society of Agronomy, opening a book for each of the principal crops, and the list occasionally published.

I am presenting the matter at this time, more to stimulate discussion of the question, especially on the two points of whether we should not adopt a naming system rather than a numbering system, owing to less confusion of names, and whether it would be desirable and useful to have a registry for information about all known varieties as well as new varieties as they are introduced. If the matter might be discussed through the columns of the Journal during the coming year it is possible that our committee on varietal nomenclature might take the matter up and have some definite recommendation to make by the time of our next annual meeting.—Cornell University, Ithaca, N. Y.

MOISTURE RELATION OF TEXAS SOILS.

G. S. Fraps.

(Read before the American Society of Agronomy, November 10, 1914.)

The object of this paper is to present briefly some of the important results of the moisture studies carried on by the Chemical Division of the Texas Experiment Station. The apparatus used in this work consists of 48 galvanized iron cans, 12″ in diameter and 24″ deep, provided with a block tin outlet at the bottom. These cans are embedded in the soil, and arranged in such a way that the water which percolates may be caught in glass bottles. Eight soils were used, there being six pots of each soil subjected to six different treatments. The data is from three years' experiments.

Relation of Soil Type to Percolation.

The eight soils may be divided in two groups, one consisting of four clays and clay loams and the other consisting of four sands and sandy loams. The average percolation from the uncultivated pots of the sandy loam group for three years is 6.36 inches, while the percolation from the clay and clay loam group is 12.72 inches; thus, the average percolation from the clay and clay loam group is double the quantity from the sand and sandy loam group. As all of the water which falls in these pots must either percolate or evaporate, it follows that the evaporation from the uncultivated clay soils is much less than from the uncultivated sandy soils.

Effects of Cultivation.

One pot of each type was cultivated to the depth of two inches and another pot was cultivated to the depth of three inches. The percolation from the sand and sandy loam soil group cultivated two inches is 9.94 inches for the three years, with 6.36 inches for the uncultivated pot. The pot cultivated to the depth of two inches in the clay series percolated 12.22 inches compared with 12.72 inches for the uncultivated.

This brings out a very striking fact, namely, that the sands and sandy loam soils had their moisture content conserved by cultivation two inches in depth, whereas, in the case of the clays and clay loams, the cultivation was of little effect. The three-inch cultivation gave slightly less percolation with the sands and sandy loams and slightly more percolation with the clays and clay loams, indicating the necessity for a deeper cultivation with the heavy soils.

Effects of Potash Salts and Manure.

Addition of sulphate of potash to the sandy soils caused a slight increase in percolation. With the clays and clay loam soils, the sulphate of potash caused a decided decrease in percolation. The effect of the potash on the latter soils was to cause them to run together, decrease the penetration of water, and increase the evaporation.

The application of manure to the different soils resulted in a decided increased percolation with the sands and sandy loams, the gain being 2.15 inches. A slightly increased precolation resulted with the clays and clay loams. With almost all the soils, the fall application of manure was more beneficial than the spring application.

Details of this work will be published in full in bulletins of the Texas Experiment Station.

Conclusion.

The most striking point brought out in this work is the fact that the clays and clay loams show little appreciable saving of moisture due to the cultivation or the application of manure under Texas conditions. There is very little more percolation from the pots which have been cultivated or which have received the manure than from the bare uncultivated pots.

On the other hand, the sands and sandy loam soils showed a decided gain in moisture by the use of cultivation and the use of manure. Both cultivation and manure increased the percolation from the pots,

indicating a decreased evaporation. It must be remembered that these results were secured under average Texas conditions, in which rather wet periods alternate with long periods of dry weather.—Texas Experiment Station, College Station, Texas.

RELATION OF CHEMICAL COMPOSITION TO SOIL FERTILITY.

(Read before the American Society of Agronomy, November 10, 1914.)

G. S. Fraps.

Three general methods are used for the purpose of studying soil fertility. The first method consists of field experiments, in which the same crop is grown with the addition of different fertilizers to different plots. Many of the difficulties occurring in this method of investigation are well known. The size of the crop is influenced not only by the fertility of the soil, but also by weather conditions, the character and location of the subsoil, and the soil moisture. It is necessary, therefore, to conduct these experiments over a period of several years, and also to make arrangements for check plots to overcome inequalities in the character of the soil. As pointed out in several papers published in the Proceedings of the American Society of Agronomy, these inequalities are sometimes very significant on soils apparently uniform in character. Differences in soil moisture in different parts of the field may seriously affect not only fertilizer tests, but varietal tests and other field tests. The results of the field tests depend not only upon the inherent fertility of the soil, but also are affected by weather conditions, soil moisture, climatic conditions, depth and character of subsoil, distribution of soil moisture, surface irregularities which affect distribution of rain, and other influences. The soil fertility is not necessarily the primary controlling condition.

The second method of experiment is by means of pot tests. In making pot tests, the soils are carefully prepared, placed in pots, and the crops grown under standard conditions with or without various fertilizer applications. The soils used in these tests are largely removed from the influence of the weather, soil inequalities, irregular distribution of moisture, depth and character of subsoil and similar influences. The results, therefore, depend to a larger extent upon the plant food of the soil. The physical character of the soil and moisture relations, however, are not entirely eliminated. Different soils are certainly different in physical character and these influence the growth

of crops in pots. The manner in which bacteria develop also influences the production of forms of nitrogen that the plant may take up. The controlling condition, therefore, is not entirely the differences in plant food, but depends also upon physical character of the soil, bacteriological condition and the other chemical constituents of the soil.

In applying the results secured by pot experiments to the field, it is difficult to estimate the differences in conditions which prevail, and to make allowances for the influence of the climatic conditions, character of subsoil, moisture conditions, etc., which prevail upon the soil in the field and not upon the soil in the pot.

A soil which shows itself to be deficient in nitrogen in pot experiments is not necessarily deficient in nitrogen in the field. In the first place, under the more favorable pot conditions, the plant makes heavy demands upon the soil nitrogen. The quantity of nitrogen demanded by the crop growing in the pot may easily exceed the crop possibility of the soil in the field, which may be limited by weather or physical soil conditions to a greater extent than by plant food. The soil would then be deficient in the pot experiment but not deficient under field conditions, since the plant food would not be the controlling condition. For this reason, it is advisable to consider not only the relative growth of the plants in the pots with or without the fertilizing element, but also the total quantity of the growth produced, and in applying the results to the field, to estimate whether or not field conditions which prevail would permit such a maximum growth. In other words, one must consider all the controlling conditions, and decide whether the limiting condition is plant food or something else.

The third method of judging the fertility of the soil is by means of chemical analysis. There are three chief different kinds of chemical analysis; first, complete estimation of all the plant food constituents by strenuous chemical treatment; second, determination of the plant food soluble in strong hydrochloric acid and third, determination of the plant food soluble in weak solvents.

The first two methods of analysis are more closely related to the wearing qualities of the soil and its ability to persist in production under cultivation. There is room for scientific study of soils along these lines, as there is considerable variation in the interpretation placed upon the results of complete analyses, or analyses with strong solvents and, as far as I know, there has never been any thoroughly scientific basis offered for such interpretations.

The estimation of the total nitrogen and the phosphoric acid and the potash soluble in fifth-normal nitric acid, which we will here term the

active plant food, is a fairly good basis for judging the immediate deficiencies of the soil. The average of a large number of pot experiments at the Texas Experiment Station shows that the active phosphoric acid, the active potash and the total nitrogen are directly related to the soil deficiencies brought out by the plant's growth. There are considerable deviations from the averages in the case of individual soil, which are being subjected to further study. Some of these deviations disappear when two or more successive crops are averaged. Very probably we will find soils or groups of soils which deviate widely. This method, however, is the best one we have at present for studying the relative deficiencies of soils by chemical methods and should serve as a basis for further work from which to draw more definite conclusions.

For the purpose of comparison, and in order to bring out more clearly the relative deficiencies of the soil, we state the results in bushels of corn per acre based on a weight of two million pounds. Table 1 shows these standards of interpretation:

TABLE 1.—*Standards of Interpretation of Soil Analysis.*

Phosphoric Acid.		Nitrogen.		Potash.	
Active Phosphoric Acid.	Corn Equivalent.	Total Nitrogen.	Corn Equivalent.	Active Potash.	Corn Equivalent.
P.p.m.	*Bu.*	%	*Bu.*	*P.p.m.*	*Bu.*
0 –10	6	.000–.02	8	0–50	29
10.1–20	12	.021–.04	13	51–100	37
20.1–30	18	.041–.06	18	101–150	51
30.1–40	24	.061–.08	23	151–200	80
40.1–60	30	.081–.10	28	201–300	120
60.1–80	35	.101–.12	33	301–400	157
80.1–100	40	.121–.14	38	401–600	182
100.1–200	45	.141–.16	43	601–800	207
200.1–400	50	.161–.18	48		

The figures given are intended to show the relative deficiencies of the soil in plant food and not the quantity of corn which the soil should produce. The actual production must vary with soil location, climate, season, etc., as well as with the soil fertility. The relation between the analysis and the field production must be studied in different sections of the country. We are making such study in Texas.

The table is useful, first, to show the probable deficiencies of a soil subjected to chemical analysis. There will be deviations from this probability; they require further study.

It is useful, second, in selecting soils for pot or field work, to test availability of fertilizers. We have found it useful indeed in this way.

It is useful, third, as an aid in the systematic study of soil fertility. By dividing the soils into groups, arranged according to their deficiency in the plant food to be studied, we can compare and study deviations further.

We must use the same caution in applying these results to field conditions, that we use in applying the results of pot experiments. A soil is deficient in nitrogen if its corn possibility for nitrogen is 12 bushels, and field conditions permit the production of 20 bushels, but the same soil is not deficient in nitrogen if field conditions permit the production of only 12 bushels. An application of nitrogenous fertilizers would not give results in the latter case unless the controlling field conditions were likewise improved.

The results of this work show that undoubtly there is a relation between the active phosphoric acid, the active potash, the total nitrogen of the soil and the soil deficiencies as shown in pot experiments; and it opens a way for more extended study of these chemical relations which are so important to scientific agriculture.—Texas Experiment Station, College Station, Texas.

THE PRODUCTION OF CORN IN HAWAII.

C. K. McClelland.

Since corn thrives so well in the Mississippi Valley and in other parts of the temperate zone, many of us have come to consider it as strictly a temperate zone crop. Its tropical origin and its adaptability, however, as well as the good crops often obtained in the tropics, indicate that corn is also a tropical cereal. In particular, Hawaii, with its wide variations in soil, precipitation and elevation, offers some conditions that favor the production of good yields of corn. The corn belt of Hawaii lies on the leeward or dry sides of the islands, at an elevation of from 3,000 to 5,500 feet. The area now planted to corn is not extensive, but it is gradually being increased as the demands of the crop become known and the need for stored feed becomes more urgent.

There are two regions especially noted for the excellence of their yields and product, the Kula region of the island of Maui and the Waimea-Waikii region of the island of Hawaii. The former extends for some 20 miles on the south slopes of Haleakala, the vast extinct crater on the island of Maui, at elevations between 3,000 and 4,500 feet; the latter occupies a similar position on the slopes of the summit

of Mauna Kea on Hawaii, but extends somewhat higher (5,500 feet) than does the Kula region. In the upper portions of these belts frost occurs.

The rainfall at any point or in any year is capricious; the higher slopes cut off the northeast trade winds and deprive the lands of any moisture from that source, so that the greater part of the rainfall comes from southerly winds or "kona" storms, which occur mostly during the winter months. The moisture from the occasional summer showers is small in amount, usually evaporating within a few hours after it falls, and it is not a factor in crop production. This means that the crop must be produced by the moisture stored in the soil during the rainy season. This effective rainfall varies greatly in amount from year to year, in some seasons being almost nothing but usually averaging from 20 to 30 inches.

The soils of the two regions are very similar in nature. They differ from most Hawaiian soils in that they contain little clay but have large amounts of silt, in which respect they are similar to the soils of the corn belt of the continental United States. The following analysis by W. P. Kelley shows the mechanical composition of a soil at Waimea:

	Per Cent.
Organic matter and combined water	25.83
Gravel and coarse sand	1.64
Fine sand	38.03
Silt	16.22
Fine silt	19.99
Clay	2.05

I am informed by Mr. A. W. Carter, the manager of Parker Ranch, that these soils produced from 35 to 40 bushels per acre in a season during which but 4 inches of rain fell, most of which was lost by evaporation. The silt and organic matter of these soils give them a large moisture-retaining capacity. The one great objection to them is that they blow easily and terrific storms of red dust are common during the late winter and spring months.

In these belts, because of their elevation, corn is always planted in the spring. Dent corn, for the most part mixed white and yellow, with rather large ears and kernels, is commonly grown; at the higher elevations an earlier variety of white dent with smaller ears and kernels is planted, the seasons here being shorter. Some attention is now being paid to the selection of seed upon the Parker ranch and they furnish almost the entire supply of home-grown, commercial seed.

At lower elevations, and in fact almost anywhere in the islands below the altitudes given, regardless of soil or climate, it is possible to produce corn, but there is much less certainty as to the result. At 800 feet, a crop of 40 bushels has been produced at Kunia on the island of Oahu and one about equally as good at the same elevation on the island of Molokai, but these results were obtained only once out of several trials, the causes of failure being insects and drought, the soils not being so retentive of moisture as those previously mentioned.

At sea level and usually at the lower elevations, attacks by leaf hoppers at the beginning of the dry season are almost sure to result disastrously to the corn crop. For this reason, it is preferable to plant corn in such localities in the fall (November to January), so that the crop will be made by the time the dry weather comes in late spring. When grown for the first time in isolated sections late-planted corn may or may not escape the depredations of the hoppers. Even early planting does not insure a crop, as the winds in January have been known to dry up the tassels and prevent pollination. The College of Hawaii has produced as much as 90 bushels per acre near Honolulu and the same year the experiment station cut test rows indicating a yield of 60 bushels per acre, but the following season neither succeeded in getting a crop for the reason just stated. It would seem, then, that the production of corn in Hawaii on any large scale will be confined to the higher elevations, although medium elevations on the windward sides are giving indications that they may also produce the crop.

Heretofore almost the entire corn area has been harvested by shucking in the field from the standing stalks, a smaller area being cut and shocked. Recently several silos have been erected, notably upon the Parker ranch, and the corn is being put up as silage and stored for emergency feed for dry seasons. The Hind, Raymond, Cornwell and possibly other ranches have also put up silos for this purpose. The Erehwon ranch on Maui and the Mokuleia ranch on Oahu are the only dairy farms having silos; the other dairies, being supplied with water for irrigation, have plenty of green feed at all seasons.—Georgia Experiment Station, Experiment, Ga.

AGRONOMIC AFFAIRS.

FOREWORD.

With this issue, the editorship of the JOURNAL passes into new hands. Five years ago, Mr. C. R. Ball became secretary of the American Society of Agronomy and began editing its publications. He collected the scattered papers presented during the preceding two years of the life of the society and published them in Volume I of the Proceedings. The next three volumes of Proceedings followed in orderly course. At the annual meeting in 1912, it was decided to begin the issuance of a periodical publication under the name of "THE JOURNAL OF THE AMERICAN SOCIETY OF AGRONOMY." Under Mr. Ball's careful guidance this publication was successfully launched and brought through the trying second summer of its infancy. When it had become a strong and lusty youngster, he expressed a conviction that the editorial as well as the secretarial duties should be transferred to other hands. It was therefore incumbent on the society to elect another secretary. When the writer was chosen to this position in November last, it was with the understanding that the duties of the secretary and the editor were to be divorced, in accordance with the recommendation of the Committee on Nominations. The Executive Committee, however, thought it best to have the secretary continue to act as editor of the JOURNAL, and that arrangement will continue in effect during the present year.

The new editor bespeaks the hearty cooperation and assistance of the membership of the society in the publication of the JOURNAL. This publication is in a peculiar sense just what its subscribers (the members of the American Society of Agronomy) make it, for on them it is entirely dependent for the matter that appears within its covers. Articles on experimentation, research, instruction and demonstration in agronomy are urgently requested. Brief articles are particularly useful, while news notes regarding agronomists and their affairs are always appreciated. The JOURNAL offers a prompt medium of publication for announcements of new discoveries and methods and for preliminary statements of interesting results of experimentation. The promptness of its issuance, however, depends very largely on the

supply of material which is available. The cooperation already extended to the present editor augurs well for the future, and leads him to believe that the pleasures of his association with the membership of the society will go far toward preventing his dual duties from becoming a burden.

THE PROBLEM OF VARIETAL NAMES.

The brief article by Professor Montgomery entitled "On Naming Varieties," which appears elsewhere in this number, brings up anew the question of the confusion of varietal names of our leading field crops. Closely allied with it is the meagerness of adequate descriptions and of historical data for even our most important varieties. The confusion of varietal names has been greatly increased in the last twenty or twenty-five years by the public clamor for new things, which has too often been met by the sending out of old varieties under new labels. Not a little of the chaos has been caused by agronomic workers themselves, who have distributed established varieties of cereals and other crops under State or Federal numbers, sometimes with no reference to the true name of the variety. More recently, the confusion has been still further augmented by the distribution of selected strains under numbers, in some cases differing from other series of numbers for the same crop only by the addition of such words as "pedigreed" or "selected." The reporting of data from varietal tests without sufficient descriptions of the varieties to make identification possible and without information as to the sources from which the material was obtained has made correlation of these tests extremely difficult.

To the writer, two remedies for this confusion seem feasible. These are: (1) The publication of adequate descriptions and historical statements when varietal data are published, or at least when a variety if first mentioned in the reports of varietal tests; and (2) the establishment by this Society of definite rules for varietal nomenclature, such as are now in use by the American Pomological Association, with the publication of names and descriptions of both old and new varieties by the Society in some such form as that suggested by Professor Montgomery. Neither of these remedies alone will be effective, but the two working together should accomplish much good. The second should eventually, in large measure, alleviate the necessity for the first. Discussion of this subject, as suggested by Professor Montgomery, will be welcomed.

MEMBERSHIP CHANGES.

The membership reported in the last issue was 397. Since that time, 1 member has been lost by death and 26 new members have been added, making the present membership 422. The changes in the membership list and the changed addresses since the last issue are as follows:

New Members.

Bledsoe, R. Page, Dept. Agron., Agricultural College, Manhattan, Kans.
Carter, L. M., College of Agriculture, Athens, Ga.
Currey, Hiram M., 953 Monroe St., Corvallis, Ore.
Damon, S. C., Experiment Station, Kingston, R. I.
Galbraith, A. J., Agricultural College, Guelph, Ontario, Canada.
Gilbert, M. B., 406 So. 15th St., Corvallis, Ore.
Kenney, Ralph, Dept. Agron., Agricultural College, Manhattan, Kans.
Lohnis, F., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Martin, John H., Bellefourche Exp. Farm, Newell, S. Dak.
New, T., 218 Delaware Ave., Ithaca, N. Y.
Olsen, Jens, 239 North 8th St., Corvallis, Ore.
Osborn, L. W., Experiment Station, Fayetteville, Ark.
Peterson, W. A., Northern Great Plains Field Sta., Mandan, N. Dak.
Plummer, J. K., Experiment Station, Raleigh, N. C.
Pritchard, Fred J., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Rice, Thos. D., Bureau Soils, U. S. Dept. Agr., Washington, D. C.
Richey, F. D., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Scales, Freeman M., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Seamans, Arthur E., Akron Exp. Farm, Akron, Colo.
Simmons, Geo. E., Dept. Agron., University of Maine, Orono, Maine.
Smith, Herbert G., Experiment Farm, Tucumcari, N. Mex.
Welch, J. S., Gooding Exp. Sta., Gooding, Idaho.
Westover, H. L., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Will, George F., Bismarck, N. Dak.
Wright, R. Claude, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Young, Y., 135 University Station, Urbana, Ill.

Members Deceased.

Pettit, J. H.

Addresses Changed.

Abbott, J. B., College of Agriculture, Durham, N. H.
Beaumont, A. B., 415 College Ave., Ithaca, N. Y.
Hungerford, De F., College of Agriculture, Fayetteville, Ark.
Klinck, L. S., University of British Columbia, Victoria, B. C., Canada.
Moorhouse, L. A., Farm Management, U. S. Dept. Agr., Washington, D. C.
Oakland, Irwin, 319 W. 10th St., Sioux Falls, S. Dak.
Robertson, A. D., Douglas, Ariz.
Suddath, R. O., Rowan County Farm Life School, China Grove, N. C.

NOTES AND NEWS.

J. B. Abbott, formerly associate in soil improvement at the Indiana station, is now state leader of county agents in New Hampshire.

Max F. Abell has been appointed an assistant in farm crops in Ohio State University.

R. T. Burdick has been promoted to an assistant professorship in agronomy at the University of Vermont.

H. N. Cobb and L. J. Obold have been appointed assistants in agronomy at the Pennsylvania college and station.

DeForest Hungerford, for nearly four years instructor in soils in the college of agriculture, University of Minnesota, on January 1 became assistant professor of agronomy in the college of agriculture, University of Arkansas.

L. S. Klinck has been appointed dean of the College of Agriculture of the University of British Columbia at Victoria. He has been succeeded as professor of cereal husbandry at Macdonald College of McGill University, Quebec, by James Murray, for several years superintendent of the Dominion Experiment Farm at Brandon, Manitoba, and more recently the manager of large farming interests in Alberta.

S. C. Jones, assistant professor of soil physics and assistant agronomist of the Kentucky university and station, resigned November 15 to become assistant in soils at the Indiana station.

C. E. Leighty of the office of cereal investigations, U. S. Department of Agriculture, was recently elected treasurer of the Washington Botanical Society to fill a vacancy. C. E. Chambliss of the same office is secretary of the society.

George Livingston, acting head of the department of agronomy in Ohio State University, is the author of a text-book of 424 pages for secondary schools entitled "Field Crop Production."

George B. Mortimer has been appointed instructor in agronomy in the University of Wisconsin.

C. E. Neff has been appointed an assistant in farm crops at the University of Missouri.

Dr. James H. Pettit, since 1901 connected with the University of Illinois and for the past several years professor of soil fertility in the college of agriculture and chief of soil fertility investigations in the Illinois station, died December 30, 1914, at Pasadena, Cal., where he

had gone in the hope of benefiting his health. Dr. Pettit was born at Lagrange, N. Y., in 1875; received his bachelor's degree at Cornell University in 1900, and his doctor's degree from the University of Göttingen in 1909. He had been a member of the American Society of Agronomy since 1910.

H. J. Patterson has resigned as president of the Maryland Agricultural College, effective July 1, 1915. In accordance with his recommendation, the office of president will be abolished and the duties will be performed by a commission consisting of a director of college work, the director of the station and the director of extension. Dr. Patterson will continue to be director of the experiment station.

E. D. Sanderson, dean and director of the West Virginia college and station, has resigned effective September 1, 1915. It is reported that he will pursue graduate studies.

S. H. Starr and E. C. Westbrook have been appointed assistants in agronomy in the Georgia State College of Agriculture.

R. O. Suddath, who has been engaged in farmers' cooperative demonstration work in Albemarle, N. C., for several months, is now instructor in agriculture in the Rowan County Farm Life School at China Grove, N. C.

J. K. Wilson, formerly an instructor in botany in Cornell University, has been appointed an assistant professor of soil technology in the same institution.

The department of agronomy of the Missouri university and station has been divided into departments of soils and farm crops, with M. F. Miller in charge of the former and C. B. Hutchinson in charge of the latter.

The department of soil technology of Cornell University moved into its new building during January. The department now has laboratories which are specially well equipped and has more space than was formerly available. Two doctorate degrees were conferred by the department in January. Those who received these degrees, with the titles of their theses, were J. K. Plummer, "Effect of Carbon Dioxid and Oxygen on Ammonification and Nitrification of Soils," and M. A. Klein, "Studies in the Drying of Soils."

Willet M. Hays, who spent the year after his retirement as assistant secretary of the U. S. Department of Agriculture in Argentina as adviser to the government in developing plans for agricultural education, is again located at Washington, D. C. He is engaged in agricultural efficiency work and announces that he is prepared to serve business and public institutions in need of advice on agricultural matters.

J. K. Plummer, who, as noted elsewhere, recently received his doctorate degree from Cornell University, is soil chemist at the North Carolina station.

Dr. H. L. Shantz, of the U. S. Department of Agriculture, delivered a lecture on "The Natural Vegetation and Agriculture of the Great Plains and the Great Basin," before the Geographic Society of Chicago, on February 26.

Association Meetings.

At the annual meeting of the Society for the Promotion of Agricultural Science held in Washington, D. C., in November, 1914, L. A. Clinton of the U. S. Department of Agriculture was elected secretary to succeed Dr. E. W. Allen. President H. J. Waters of the Kansas State Agricultural College was reelected president of the society.

The American Genetic Association, at its annual meeting in Washington, D. C., January 12, 1915, reelected all of its officers whose terms had expired. These included David Fairchild, president; W. E. Castle, vice-president; George M. Rommel, secretary; Corcoran Thom, treasurer; and Alexander Graham Bell, W. E. Castle, and Bleecker van Wagenen, members of the council. The address of the association is 511 Eleventh St. N. W., Washington, D. C.

The Association of American Agricultural Colleges and Experiment Stations, at its meeting in Washington, D. C., on November 11–13, 1914, elected the following officers: President, E. A. Bryan of Washington; vice-presidents, J. H. Worst of North Dakota, T. F. Hunt of California, C. D. Woods of Maine, P. H. Rolfs of Florida, and C. A. Lory of Colorado; secretary-treasurer, J. L. Hills of Vermont, and bibliographer, A. C. True of Washington, D. C. The executive committee for the coming year are W. O. Thompson of Ohio, chairman; H. J. Waters, Kansas; Brown Ayres, Tennessee; W. H. Jordan, New York; and H. L. Russell, Wisconsin.

The fourth annual meeting of the American Society of Milling and Baking Technology was held at Washington, D. C., Nov. 18, 1914. Reports were made of experiments with baking powders by Dr. T. J. Bryan; on analytical tests by B. R. Jacobs; on collaboration in milling by L. A. Fitz; and on methods of baking by C. H. Bailey. The following officers were elected: President, R. Harcourt of the Ontario College of Agriculture; vice-president, R. W. Thatcher of the Minnesota College of Agriculture; and secretary, J. A. LeClerc of the U. S. Department of Agriculture.

The first meeting of Section M, Agriculture, of the American

Association for the Advancement of Science, was held at Philadelphia, December 30, 1914. The vice-presidential address of the section was delivered by Professor L. H. Bailey, his subject being "The Place of Research and of Publicity in the Forthcoming Country Life Development." The other papers of the meeting were on the general topic of rural economics, these being presented by Assistant Secretary of Agriculture Vrooman, Prof. G. N. Lauman of Cornell University, Dr. T. N. Carver of Harvard University, and Mr. Chas. J. Brand of the Federal Office of Markets and Rural Organization. Dean E. Davenport of the University of Illinois was elected vice-president and chairman of the section for the ensuing year; Dr. A. C. True of the Office of Experiment Stations was chosen member of the General Committee of the Association; Dr. W. A. Taylor of the Bureau of Plant Industry, member of the council; and President Kenyon L. Butterfield of Massachusetts, a member of the sectional committee (for five years).

During the week of August 2–7, 1915, as noted elsewhere under "Coming Events," the American Association for the Advancement of Science and its affiliated societies will meet in San Francisco, Cal. Among the affiliated societies are the American Genetic Association and several others less closely connected with agronomy. There will be a series of addresses on agriculture during the week, particularly on problems of food supply and of agricultural conservation. The following week, the Association of American Agricultural Colleges and Experiment Stations will meet at Berkeley, on the campus of the University of California. In connection with this meeting, numerous other agricultural organizations will hold their annual sessions, including the American Society of Agronomy. It is probable that this Society will meet on August 9 and 10.

Changes in the Department of Agriculture.

In accordance with the authorization given him by the agricultural appropriation act for the fiscal year ending June 30, 1915, the Secretary of Agriculture, in submitting the estimates to Congress for the fiscal year ending June 30, 1916, makes provision for the reorganization of certain lines of work in the Department of Agriculture. This authorization was requested by the Secretary in the interests of efficiency and flexibility. Among the changes recommended by the Secretary of Agriculture in his annual report for 1914 and included in the appropriation act now before Congress, those of special interest to agronomists include: The consolidation of the work in irrigation and

drainage now in the Office of Experiment Stations and of rural architecture in the Bureau of Plant Industry with the present Office of Public Roads under the new title of "Office of Public Roads and Rural Engineering;" the union of the farmers' demonstration work, both north and south, with the Office of Experiment Stations under the new name of "States Relations Service;" the separation of the Office of Farm Management from the Bureau of Plant Industry, attaching it to the Office of the Secretary; and the transfer of the soil-fertility investigations from the Bureau of Soils to the Bureau of Plant Industry. A number of other less important changes are planned. In addition, the regulatory, the research and the extension activities within the various bureaus are to be segregated so far as possible, without changes in the bureau organization.

Reports of Local Sections.

Annual Report of the Kansas Section.—Secretary C. C. Cunningham of the local section of the American Society of Agronomy at the Kansas State Agricultural College reports that the section meets monthly during the college year. At each meeting, two papers are presented on subjects of agronomic interest. These papers usually report the results of recent experiments at the Kansas station. The membership of the section is twenty-one.

Annual Report of the Washington (D. C.) Section.—The Washington section of the American Society of Agronomy was organized December 10, 1913. Four meetings were held during the winter of 1913–14, at which the average attendance was 44. The membership of the section was 71, of whom 45 were members of the American Society of Agronomy. At the four meetings, a total of 14 papers were read; in the discussion of these papers a large number of the members participated.

Meeting of the Washington Section on Dec. 18.—The fifth regular meeting of the Washington section was held at the Cosmos Club December 18, 1914. Mr. H. N. Vinall presented a paper entitled "Natural and Artificial Hybrids of Sorghum and Johnson Grass," in which the peculiarities of root, stem and leaf growth of these hybrids were discussed. Some which have the free stooling habits and rapid growth of the Johnson grass but lack the perennial root stocks which make that grass a pest promise to become valuable forage crops. Mr. P. H. Dorsett, who was a member of the agricultural exploration party sent to Brazil in 1914 by the Department of Agriculture, talked on "Some Phases of Brazilian Agriculture." He gave much interest-

ing information on the forage, grain, fruit and coffee crops of Brazil. Both papers were illustrated and were followed by some discussion. At the business meeting, officers for the ensuing year were elected as follows: President, H. N. Vinall; vice-president, C. E. Leighty; secretary-treasurer, P. V. Cardon; and additional members of the executive committee, J. C. Thysell and A. C. Dillman.

Meeting of the Washington Section on Jan. 20.—The sixth regular meeting of the Washington section was held at the Cosmos Club January 20, 1915. The following program was presented:

Comparative Effect of Cultural and Climatic Factors in Crop Production on the Great Plains, by W. W. Burr.

Grain Crop Mixtures, by C. W. Warburton.

Agriculture of the Peruvian Andes, by H. V. Harlan.

Mr. Burr presented data from the records of numerous experiments conducted by the Office of Dry-Land Agriculture with spring wheat and oats in the Great Plains which indicated strongly that climatic conditions had far more effect on crop yields than had been obtained from various tillage methods. This fact was particularly evident on soils with slight capacity for the storage of moisture. Mr. Warburton's paper is presented elsewhere in this issue. Mr. Harlan talked very interestingly of his experiences of a year ago when he investigated the agricultural possibilities of the Titicaca highlands in Peru for a syndicate of English land-holders there. His talk was illustrated with a number of lantern views from photographs taken during his visit. The evening closed with a social hour with refreshments.

COMING EVENTS.

Under this caption it is proposed to keep standing a schedule of coming meetings of various organizations more or less closely connected with agronomy. Secretaries of such bodies are invited to furnish information regarding their meetings.

American Society of Agronomy.

Special meeting, Mandan, N. Dak., July 14–16, 1915, in connection with the meetings of the Great Plains Cooperative Association.

Annual meeting, University of California, Berkeley, Cal., August 9–10, 1915. (In connection with meeting of Assoc. Agric. Coll. and Exp. Stations.)

American Association for the Advancement of Science.

San Francisco, Cal., August 2–7, 1915.

AMERICAN ASSOCIATION OF AGRICULTURAL COLLEGE EDITORS.

Madison, Wis., June, 1915.

AMERICAN GENETIC ASSOCIATION.

San Francisco, Cal., August 2–5, 1915.

ASSOCIATION OF AGRICULTURAL COLLEGES AND EXPERIMENT STATIONS.

University of California, Berkeley, Cal., August 11–13, 1915.

GREAT PLAINS COOPERATIVE ASSOCIATION.

Mandan, N. Dak., July 14–16, 1915.

LOCAL SECTIONS.

CORNELL UNIVERSITY AND EXPERIMENT STATION.

President, Millard A. Klein.
Secretary, ————————————.

KANSAS AGRICULTURAL COLLEGE AND EXPERIMENT STATION.

President, W. M. Jardine.
Secretary-Treasurer, C. C. Cunningham.

WASHINGTON, D. C.

President, H. N. Vinall.
Secretary-Treasurer, P. V. Cardon.

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STUDIES IN THE DRYING OF SOILS.[1]

MILLARD A. KLEIN,

CORNELL UNIVERSITY, ITHACA, N. Y.

(Contribution from the Department of Soil Technology, Cornell University.)

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[1] A thesis submitted to the faculty of the Graduate School of Cornell University in partial fulfillment of the requirements for the degree of Doctor of Philosophy by Millard Alschuler Klein, B.Sc. Ithaca, N. Y., February, 1915. Received for publication March 2, 1915.

Introduction.

The drying of the soil by exposure to intense sunlight for some time has been made use of in certain arid regions of India to increase its productiveness. Since the drying of the soil in an arid region has a stimulating effect on crop growth, it is to be expected that the lowering of the moisture content in soils of the more humid regions, during seasonable changes, will influence their productiveness. The drying of the soil is a process that depends entirely on the climatic conditions, the degree and duration depending on the amount and distribution of the rainfall in the region concerned. In a study of the increased productiveness due to drying it will be necessary to consider the changes in the physical, chemical, and biological conditions of the soil.

The change in the physical condition of the soil due to drying may be easily observed in the field. A better tilth is obtained as shown by an increased granulation. This increased granulation is to a great extent due to the flocculation of the colloidal material.

The changes in the chemical composition due to drying have been studied by many investigators in relation to the amount of plant food recoverable when a sample has been previously dried, under various conditions and temperatures. Great differences in the amount of plant food recovered have been observed when a sample has been previously dried, which would show that the drying of the soil in the field may greatly influence the chemical composition. In the last decade much attention has been given to the biological changes which are taking place in the soil. In this connection drying has been considered as a partial sterilization, as the results have been similar to those obtained from a partial sterilization with steam or antiseptics.

The great importance of the biological factors cannot be ignored in the study of the drying of the soil, but at the present status of soil investigation they must be studied in connection with the biochemical changes produced.

It is the purpose of the investigation to study the effect of drying a soil on crop yield and its correlation with certain chemical and physiological changes taking place in the soil.

Review of Literature.

The successive drying and wetting of a soil greatly affects its physical condition. These processes cause an increased granulation, reducing the size of the granules and forming lines of weakness and cracks. In many ways this process is observed in the field but little data have been obtained experimentally showing the effect of successive drying and wetting upon the physical condition.

Wollny (1897)[2] studied the effect of drying and wetting a soil on the volume change. The results show that a decrease in volume is obtained by drying and wetting.

Cameron and Gallagher (1908) have shown that by repeated drying and wetting of a soil a point is reached where the volume on contraction due to drying is equal to the expansion on wetting. This condition they call a "natural packing" of the soil.

Fippin (1910) measured the effect of a repeated wetting and drying on clay soil by the force necessary to cause penetration. This force is reduced one half by five dryings and to one third by twenty dryings, granulation being increased 60 percent.

The effect of drying a soil has long been a problem to the soil chemist. Warington (1882) recognized the importance of drying a soil on the nitrate content. He found a reduction of nitrates in an oven-dried sample, a greater reduction when slowly oven-dried and an increase when air-dried. He advises drying a sample in a room, at 55°–60° F., for twenty-four hours as he found very little nitrification taking place at this temperature.

Richter (1896) dried a garden soil in an oven at 100° C., and found an increase in the absorptive power for water and an increase in the nitrogen and soluble organic matter.

The investigations of King (1905) on the amounts of plant food recoverable from field soils gives us the most valuable data on this subject. King compared the amounts of plant food recovered from fresh soil, soil air-dried, and soil dried in an oven at 110° C. He found more nitrates, phosphates, sulfates, bicarbonates, and silica, but less chlorides, recoverable from an oven-dried than from the fresh sample. The increase was greater than by washing the fresh sample with five times its weight in water. He considers that the increase may be partly due to the releasing of the salts locked up in the organic matter. Another cause may be what he calls the "fixing" power of soil grains, causing a concentration near the surface of the soil particles which when dried are covered with the residues of evaporation and allow a greater solution than in the fresh soil. He also considers that the granular condition of the soil would allow a large amount of water to be carried within the granules, the subsequent drying bringing the salts to the surface and making them more accessible to solution.

Leather (1912) found an increase in the nitrates in soils that had been dried in the sun at Pusa, India, the increase being four times as great as in the fresh sample.

Kelley and McGeorge (1913) studied the effect of drying on the

[2] Dates in parentheses refer to bibliography at end of paper.

mineral constituents of Hawaiian soils. On the average, drying the soils at 100° C. increased the water-soluble carbonates, phosphates, manganese, calcium, magnesium, potassium, aluminum, sulphates, and silica over the air-dried soil. They consider that the causes involve many factors, both chemical and physical, as flocculation, dehydration, oxidation, and the altering of the film pressure.

Investigations have shown that drying a soil has an effect on its biological condition. These changes must be studied in relation to the chemical changes produced and may be considered biochemical. Early bacteriologists considered that the soil was merely sterilized when heated. In recent investigations soils heated to temperatures lower than 100° C. have been considered as partially sterilized. The drying of a soil may therefore be considered as a partial sterilization.

Russell and Smith (1905) find that nitrifying organisms can be easily killed by an insufficient amount of moisture or by drying at 100° C.

Rahn (1907) has made the most extensive investigations on the effect of drying soils on their physiological condition. From studies on carbon dioxid and acid production in sugar solutions and ammonia production in peptone solutions he finds a greater bacteriological activity in a soil previously dried at room temperature than in the same soil kept moist. Greater differences were found in a rich garden soil than in a sandy soil. The number of bacteria were decreased, and this he considers difficult to explain if the effect is on the bacterial activity. He believes that the effect can not be physical as an extract of the soil or a water suspension shows the same order of differences; nor can it be the decomposition of the soil constituents because when phosphates and asparagin were added the same differences resulted. Mustard grew better on a soil previously dried.

Pickering (1908) found that the heating of soils inhibited the germination of certain seeds, and that the alteration of the soil began at temperatures as low as 30° C. No appreciable destruction of the detrimental substance occurred when the soil was kept for several months in a moderately dry condition.

Further experiments by Pickering (1908) show an increase in the soluble organic material in soils heated to 30°, 60°, and 80° C. and then exposed to the air for two months at summer temperatures and watered occasionally. At higher temperatures a decrease was obtained.

Russell and Hutchinson (1909) (1913) have studied the effect of partial sterilization by heating with steam. They find an increased availability in plant food and an increased plant growth. This they believe is related to a change in the bacterial flora, the larger phago-

cytic organisms being killed and the beneficial bacteria being allowed to increase.

Howard (1910) recognizes this effect in the soils which are exposed to the intense sunlight of India. The fertility is increased, and he believes that this may be due to an inhibiting effect of partial sterilization on the protozoa, as reported by Russell and Hutchinson on the studies of soils heated in the laboratory.

Russell (1910) recognizes the observation made by Howard and believes that the soils exposed to sunlight may be dried and heated sufficiently to remove the factor which limits the productiveness of the soil. This is shown in further investigations by Russell and Hutchinson (1913). They exposed the soil to a temperature of 35–38° C. for varying intervals. Upon remoistening the samples, it was found that the factor which is detrimental to the fertility is temporarily inhibited by ten days' drying. Soil exposed to sunlight for ten days behaves in the same manner. The detrimental organisms are killed at 55–60° C. and suffer considerably at lower temperatures (40° C.). They conclude that drying a soil has the same effect as heating at low temperatures; that is, it only temporarily eliminates the detrimental factor.

Greig-Smith (1911) has shown that bacteriotoxins are destroyed at 94° C. He holds that upon remoistening the soil the more resistant bacteria multiply and become more numerous because of the absence of bacteriotoxins. Sunlight and air-drying the soil destroy the toxins.

Ritter (1912) made studies similar to those of Rahn and found that bacterial activity increased on drying a soil. A dried soil gave quicker and more intensive action. "Heavy" soil showed a greater difference than a "light" soil. A repeated drying and wetting caused a decrease in the activity. He concludes that the physical condition of a soil goes hand in hand with the physiological condition.

Fischer (1913) discusses the work of Rahn and Ritter and comments on their conclusions. He believes that more depends on the chemical composition than on the bacterial activity. Oxidation must be the principal factor, as the nitrates are increased on drying, yet the nitrifying organisms are killed. He thinks that colloids and surface tension must play an important part as a factor in this induced oxidation.

Sharp (1913) studied the effect of drying by investigating soils that had been dried and kept in tightly stoppered bottles for thirty years. These soils still contained an average of 358,000 organisms per gram. Ammonifying organisms were present, but nitrification occurred only

feebly in two of the nine soils examined. The nitrogen-fixing power was maintained but the Azotobacter forms were absent in all except one soil. He concludes that there is no relation between numbers and physiological efficiency.

Russell and Petherbridge (1913) found that plants grown on soils heated to 55° C. show an acceleration in early growth succeeded by a steady growth. An increase in plant food in the soil and an increase in nitrogen, potassium, and phosphorus was found.

Lyon and Bizzell (1913) found that the drying of the soil during seasonal moisture changes has both increased and decreased the nitrates, depending upon the kind of crop grown. In an unplanted plot an increase in soil moisture after a dry period has in most cases increased the nitrates in the soil.

Experiment 1. The Effect of a Previous Drying of the Soil to Different Moisture Contents on Plant Food in the Soil and Plant Growth.

The object of the investigation is to study the effect of drying the soil on its chemical and biological condition and on plant growth. Previous investigations on the drying of the soil show that changes occur in the soil that greatly affect its fertility. That the effect is neither physical, chemical, nor biological, but a combination of the three, has been generally accepted.

In the field the soil is continually being subjected to an intermittent wetting and drying. The length of drying and the moisture content depend upon the amount and variation of the rainfall in the region concerned.

In a humid region the period of drying is short and the moisture content to which the soil is dried is usually not very low. In an arid region the soil is sometimes air-dry or nearly so and remains dry for some length of time.

With this in view the plan of the experiment was to determine under controlled conditions the effect of drying the soil to different moisture contents on plant food in the soil and on plant growth.

Soils Used.

Two soils were used in the experiment, differing only in organic matter. Soil No. 1 is a heavy clay loam known as Dunkirk clay loam. It contains comparatively little organic matter, but the fertility is good. Soil No. 2 is the same type of soil, but the organic matter had been greatly increased by piling up timothy sod and allowing it to

decompose. Some of the organic matter had not entirely decomposed. This caused some difficulty in preparing the soil for the pots, as the undecomposed organic matter would tend to mass together.

Method of Experimentation.

The two soils were brought in from the field December 9, 1911, thoroughly mixed and put in 3-gallon pots. Each pot contained 11 kilograms of wet soil. A moisture determination was made at this time and the pots were brought to complete saturation (40 per cent). All pots were removed to the field-house January 11, 1912. On February 28, 1912, the pots were brought in from the field-house. While the pots were in the field-house the soil was frozen and a number of them were broken. The remaining pots were then allowed to dry in the greenhouse until they reached their permanent moisture content, as shown in Table 1.

TABLE 1.—*The Moisture Content of Pots Used in the Experiment.*

Soil No. 1.				Soil No. 2.			
Series 1, Unplanted.		Series 2, Planted at 25 Percent.		Series 1, Unplanted.		Series 2, Planted at 25 Percent.	
Pot No.	Moisture Content.	Pot No.	Moisture Content.	Pot No.	Moisture Content.	Pot No.	Moisture Content.
	Percent.		*Percent.*		*Percent.*		*Percent.*
421	15	401	15	447	15	431	15
422	15	403	15	448	15	432	15
424	20	408	15	449	15	433	15
425	20	411	20	450	20	434	20
426	25	412	20	451	20	435	20
427	25	430	20	452	20	436	20
428	30	415	25	453	25	437	25
429	30	416	25	454	25	438	25
		417	25	455	25	439	25
		418	30	456	30	440	30
		419	30	457	30	441	30
		420	30	458	30	442	30
				459	40	443	40
				460	40	444	40
						445	40

The pots of the highest water content were at saturation. In soil No. 1 the highest water content was at 35 percent, but after a few months the water stood on the surface of the soil and it became necessary to drop this water content to 30 percent. Just the opposite condition was found in soil No. 2, and the highest water content of 35 percent was raised to 40 percent. The moisture content as shown in Table 1 gives this corrected percentage for the pots kept at saturation.

The pots were kept at the different moisture contents as shown in

Table 1 until December 19, 1912. They were then divided in two series. One series was prepared for planting by bringing all pots to 25 percent moisture content, while the second series was kept bare at the different moisture contents. The division of the pots in two series is shown in Table 1.

On January 14, 1913, all pots of series 1 were planted to Galgalos wheat. Forty seeds were planted in each pot. A good germination was secured and the seedlings were thinned to 12 plants.

Effect of Previous Moisture Content on Plant Growth.

At an early stage soil No. 1 allowed a better growth. On April 29, 1913, the pots that had been previously held at a high moisture content showed a poorer growth than those held at a low moisture content. At the time of heading the plants in pots 440, 441, and 442 were much smaller than others of the same series. On June 4, the plants in pots 437, 438, and 439 were making the best growth.

On May 22, it could be seen that the drying out of a soil to a low moisture content previous to planting was having a beneficial effect on plant growth. In soil No. 2 the pots which had been held at 30 percent moisture content previous to planting showed a poorer growth than the ones previously held at 40 percent.

A more luxuriant growth was obtained on soil 2, the great difference evidently being due to the greater amount of organic matter in soil No. 2 or to some factor depending upon the organic content.

On June 17, the plants were fully headed but were not entirely ripe. It was necessary to harvest on this date, however, owing to attacks made upon the plants by rodents in the greenhouse. The plants on soil No. 1 were somewhat nearer maturity than those on Soil No. 2. The plants from all pots were hung in the greenhouse and allowed to ripen completely.

Millet was immediately planted, but a very poor growth of the seedlings was obtained. It was therefore replaced by buckwheat.

The pots containing soil No. 1 had become so compact that it was necessary to lower the water content from 25 percent to 22 percent. During the growth of the buckwheat little difference could be observed. It was evident that the pots had reached a point where the previous moisture content had little effect, or that buckwheat was not appreciably affected by changes in the moisture content.

Effect of Previous Moisture Content on the Morphology of Wheat.

A study of the effect of drying a soil to different moisture contents on the morphology of wheat is shown in Table 2. The results with

soil No. 1 do not show a great difference in the first three water contents (15, 20, and 25 percent). A great decrease will be noted in pots 418, 419, and 420 in the number of culms per pot, but only a slight difference in the other characters. These pots were held at saturation before planting and a poor physical condition of the soil was noticeable.

TABLE 2.—*Effect of Previous Moisture Content on the Morphological Characters of Wheat.*

Pot No.	Previous Moisture Content.	Culms per pot (12 Plants).	Length of Culm.	Length of Head.	Grains per Head.	Empty Spikelets.	Spikelets with one Grain.	Spikelets with two Grains.	Spikelets (Total.)	Nodes per Culm.
				Soil No. 1						
	P. ct.		*Inches*	*Inches*						
401	15	25	34.7	3.08	16.8	2.8	7.2	4.8	—	4.0
403	15	25	34.7	3.00	13.4	3.4	7.0	4.0	—	3.7
408	15	25	37.3	3.30	16.5	2.7	6.0	5.2	—	3.3
Ave.	15	25	35.6	3.12	16.0	3.0	6.7	4.7	14.4	3.7
411	20	26	33.5	3.20	15.4	2.3	7.1	4.2	—	3.9
412	20	20	42.5	3.20	17.0	2.4	6.5	5.1	—	4.0
430	20	26	36.6	3.20	16.3	3.1	7.0	4.8	—	3.9
Ave.	20	24	37.5	3.20	16.0	2.6	6.8	4.7	14.1	3.9
415	25	25	34.8	2.80	14.7	2.5	7.0	4.1	—	4.0
416	25	22	35.3	3.00	13.8	3.0	7.1	3.3	—	3.6
417	25	19	34.0	2.80	13.0	3.0	7.0	3.2	—	3.6
Ave.	25	22	34.7	2.95	14.0	2.8	7.0	3.5	13.3	3.7
418	30	12	31.3	2.40	10.5	3.3	6.3	2.0	—	4.0
419	30	13	34.5	2.50	12.0	2.9	6.1	3.0	—	3.7
420	30	13	31.6	2.45	10.3	1.6	6.3	2.2	—	3.5
Ave.	30	13	35.8	2.45	11.0	2.5	6.2	2.4	11.1	3.7
				Soil No. 2						
431	15	36	30.5	3.36	19.0	2.6	5.4	6.4	—	3.4
432	15	34	30.3	3.50	18.3	2.4	6.0	6.3	—	3.5
433	15	44	34.4	3.40	17.0	2.5	5.3	5.8	—	3.5
Ave.	15	38	31.7	3.40	18.1	2.5	5.6	6.2	14.3	3.5
434	20	30	28.5	3.20	14.1	2.2	5.2	6.0	—	3.7
435	20	34	29.6	3.20	16.8	2.2	5.5	5.5	—	3.5
436	20	34	30.0	3.60	16.9	2.0	5.0	7.3[1]	—	3.5
Ave.	20	33	29.4	3.30	15.9	2.1	5.2	6.3	13.6	3.6
437	25	33	32.4	3.60	18.6	2.0	5.2	6.6	—	3.7
438	25	35	30.6	3.40	18.5	2.0	6.0	6.3	—	3.6
439	25	27	34.3	3.40	16.6	1.7	5.2	6.5	—	3.9
Ave.	25	32	32.4	3.50	17.9	1.9	5.5	6.5	13.9	3.7
440	30	17	34.2	3.40	17.7	2.1	4.0	6.7[2]	—	3.6
441	30	17	23.2	2.50	13.0	2.3	4.4	4.4	—	3.2
442	30	13	22.7	2.30	9.0	3.5	5.0	2.0	—	3.0
Ave.	30	16	26.7	2.70	13.2	2.6	4.5	4.4	11.5	3.3
443	40	34	27.7	3.00	14.5	2.4	6.5	4.0	—	3.3
444	40	41	30.0	3.10	18.1	2.7	6.2	6.0	—	3.7
445	40	41	30.3	3.40	16.8	3.2	6.2	5.2	—	3.5
Ave.	40	38	29.3	3.20	16.8	2.8	6.3	5.1	14.2	3.5

[1] Also 5 three-grained spikelets.

[2] Also 7 three-grained spikelets.

In soil No. 2, greater differences in the morphological characters due to the effect of the previous moisture content could be noted. Here, as in the plant growth, the soil that had been held at 30 percent moisture content shows the poorest results. There is a similarity between the pots which had been held at 15 percent and those at 40 percent, the average number of culms per pot being as great in the 40 percent as in the 15 percent pots.

Comparing the two soils, we find a greater number of culms per pot in soil No. 2, but the length of culms is somewhat less in this soil. The greater number of spikelets with one grain were found on the plants in soil No. 1, and the greater number with two grains were found on the plants in soil No. 2. It will be seen that in soil No. 1 there was a decrease in the number of grains per head as the moisture content was increased, while in soil No. 2 there was little difference as affected by the different moisture contents.

Effect of Previous Moisture Content on Crop Yield.

A large number of investigators have studied the effect of different moisture contents on crop yield. They do not, however, consider the possible influence of the moisture condition of the soil before planting.

In this investigation the soil was kept at the different moisture contents for ten months before planting. At the time of planting all pots were brought to an optimum water content and the weights recorded. During plant growth the pots were kept at this content by adding distilled water every day and bringing the pots to standard weight. Under this plan any differences in the amount of dry matter produced in the crop must be due to the effect of the previous moisture content and not to differences during the growth of the plants.

As the two soils differ only in organic content, a comparison of the results should show the influence of organic matter on the factors effecting the previous drying out of a soil to various moisture contents. The effect of the previous conditions of soil moisture on the production of dry matter is shown in Table 3.

In soil No. 1, the greatest weight of dry matter in the first crop, both grain and straw, is found in the soil that had been previously dried to 15 percent, a somewhat smaller yield at 20 percent and at 25 percent, and a decided decrease at 30 percent. The soil that was held at 30 percent was reduced to 25 percent at the time of planting. The same order of differences was found in soil No. 2, except that when 40 percent is reached there is a decided increase over the 30 percent. In this series the soil that was held at 40 percent was reduced to 25 percent at the time of drying.

In soil No. 2, a moisture content of 40 percent must be compared to the content of 30 percent in soil No. 1, as in both cases we have complete saturation for each soil. In the clay loam pots which had been previously held at saturation the yield of dry matter is smallest, but in the organic clay loam pots which had been held at saturation the yield is as large as those with the lowest moisture content. If we consider that the lowering of the moisture content in the pots at 40 percent moisture content is an effective drying out previous to planting, there is decided increase due to drying just before planting.

TABLE 3.—*Effect of Previous Moisture Content on Weight of Dry Matter of Wheat and Buckwheat Produced.*

Soil No. 1.					Soil No. 2.				
Pot No.	Previous Moisture Content.	Wheat.		Buckwheat.	Pot No.	Previous Moisture Content.	Wheat.		Buckwheat.
		Grain.	Straw.				Grain.	Straw.	
	P. ct.	*Grams*	*Grams*	*Grams*		*P. ct.*	*Grams*	*Grams*	*Grams*
401	15	18.2	30.3	5.9	431	15	20.5	42.3	8.8
403	15	17.4	28.7	4.5	432	15	17.0	39.0	9.0
408	15	19.1	31.8	4.7	433	15	23.2	45.7	9.4
Ave.	15	18.2	30.3	4.7	Ave.	15	20.2	42.3	9.1
411	20	18.5	29.5	4.5	434	20	15.8	30.6	9.0
412	20	15.8	26.6	4.9	435	20	16.3	34.5	9.6
430	20	20.0	33.2	4.0	436	20	21.7	42.5	9.5
Ave.	20	18.1	29.8	4.5	Ave.	20	17.8	35.9	9.3
415	25	16.6	27.0	4.0	437	25	15.8	41.9	9.9
416	25	13.9	25.1	4.0	438	25	16.8	40.1	10.8
417	25	11.4	20.6	5.5	439	25	14.4	33.9	9.2
Ave.	25	14.0	24.3	4.5	Ave.	25	15.5	38.6	9.9
418	30	4.9	10.0	—	440	30	8.8	22.1	8.0
419	30	5.2	12.5	6.2	441	30	5.2	11.3	7.4
420	30	6.3	12.7	6.3	442	30	2.4	7.7	7.2
Ave.	30	5.5	11.7	6.3	Ave.	30	5.5	13.7	7.5
					443	40	14.6	28.6	9.0
					444	40	22.9	46.5	10.0
					445	40	20.2	41.6	10.8
					Ave.	40	19.3	38.6	9.9

This, however, is not the case in the 30 percent moisture content pots which have also been lowered to 25 percent before planting.

The effect of drying to lower moisture contents previous to planting has been to increase the crop yield, as is conclusively shown in soil No. 1 and also in soil No. 2, if the lowering of the 40 percent moisture content before planting be so considered.

With the second crop, buckwheat, there has been little effect. There

is, however, a greater increase in the yield of soil No. 2 over soil No. 1 than in the first crop.

Effect of Previous Moisture Content on the Total Nitrogen in the Crop.

The results obtained in the determination of the total nitrogen in the dry matter of the grain and straw are shown in Table 4. It has been repeatedly shown that plants grown under different moisture conditions show a variation in the amount of plant constituents found in the dry matter. A greater crop growth usually causes a smaller percentage of nitrogen in the plant. On the other hand, if the available nitrogen in the soil is increased by an increase in the moisture content, an increase may be found in the percentage of nitrogen in the crop. The chemical constitution of the soil must be a factor, more especially in the soluble organic matter.

TABLE 4.—*Effect of Previous Moisture Content on Total Nitrogen in the Crop.*

Soil No. 1.								Soil No. 2.							
Pot No.	Previous Moisture Content.	Total Nitrogen.						Pot No.	Previous Moisture Content.	Total Nitrogen.					
		Wheat.				Buckwheat.				Wheat.				Buckwheat.	
		Grain.	Ratio.	Straw.	Ratio.	Total.	Ratio.			Grain.	Ratio.	Straw.	Ratio.	Total.	Ratio.
	Per-cent.	*Per-cent.*		*Per-cent.*		*Per-cent.*			*Per-cent.*	*Per-cent.*		*Per-cent.*		*Per-cent.*	
401	15	1.49	—	.27	—	1.63	—	431	15	3.26	—	1.02	—	2.07	—
403	15	1.68	—	.26	—	1.62	—	432	15	3.30	—	1.13	—	2.25	—
408	15	1.60	—	.25	—	—	—	433	15	3.26	—	1.18	—	1.84	—
Ave.	15	1.59	100	.26	100	1.63	100	Ave.	15	3.27	100	1.11	100	2.05	100
411	20	1.73	—	.26	—	1.74	—	434	20	3.24	—	1.17	—	2.30	—
412	20	1.60	—	.26	—	1.82	—	435	20	3.25	—	1.16	—	2.10	—
430	20	1.48	—	.29	—	1.81	—	436	20	3.26	—	.95	—	2.04	—
Ave.	20	1.60	100	.27	103	1.79	109	Ave.	20	3.25	99	1.09	98	2.15	104
415	25	1.63	—	.26	—	—	—	437	25	3.32	—	1.15	—	2.09	—
416	25	1.67	—	.25	—	1.45	—	438	25	3.27	—	1.18	—	2.15	—
417	25	1.72	—	.27	—	1.62	—	439	25	3.43	—	1.12	—	2.18	—
Ave.	25	1.67	104	.26	100	1.53	94	Ave.	25	3.34	102	1.15	103	2.14	104
418	30	1.88	—	.30	—	1.66	—	440	30	3.06	—	1.60	—	2.35	—
419	30	1.71	—	.39	—	—	—	441	30	2.88	—	1.60	—	2.40	—
420	30	1.53	—	.28	—	1.71	—	442	30	3.26	—	1.60	—	2.42	—
Ave.	30	1.71	107	.32	107	1.68	103	Ave.	30	3.07	93	1.60	145	2.39	116
								443	40	3.36	—	1.25	—	2.22	—
								444	40	3.31	—	.88	—	1.56	—
								445	40	3.34	—	.92	—	1.49	—
								Ave.	40	3.34	102	1.01	91	1.46	71

The results presented in Table 4 show that there has been no effect on the nitrogen of the crop resulting from a difference of the previous moisture content. A comparison of the two soils shows on the average twice as much nitrogen in the plants grown in the soil high in organic matter as in the same soil low in organic content. As these soils differ only in organic content and the results show practically no difference due to water content, the difference in the percentage of nitrogen in the dry matter must be caused through some factor due to the organic matter.

Effect of Previous Moisture Content on Water Soluble Matter.

It has been shown by a number of investigators that the complete drying of the soil causes an increase in the soluble salts recoverable from a water extract. However, in this investigation the soil has in no case been dried to an air-dry condition.

The results presented in Table 3 show that a lowering of the moisture content previous to planting has caused an increase in the plant growth. In order to determine whether this increase was related to an increased amount of plant food, determinations were made on the total solids, nitrates, potassium, and calcium in the water extract and phosphorus in a fifth-normal acid extract.

It might be expected that the greater plant growth in the soil high in organic matter would result from the large amount of plant food carried in the organic material. Water extracts were made from soils from all the pots immediately after the second crop was harvested, by adding 500 c.c. of distilled water to 100 grams of the soil and filtering through a Pasteur-Chamberlain water filter.

Total Solids.—Table 5 shows the results obtained in the determination of the total solids from a water extraction of the soil sample. It will be seen from this table that low water content reduces the total solids in the unplanted clay loam, while in the planted series of this soil there is little difference in the results. The results with the soil high in organic matter show an increase in the total solids in both the planted and unplanted series with an increased moisture content.

Considering the effect upon the clay loam, it is evident that drying the soil to a lower moisture content has increased the water-soluble matter. The planted series of this soil shows this same increase, although at the time of planting all pots were brought to the same moisture content. The opposite effect in the organic clay loam must be attributed to the greater amount of organic matter. It is evident that the lowering of the moisture content has had no effect on the total solids recovered, as the amounts increase with the increased water content.

TABLE 5.—*Effect of Previous Moisture Content on Soluble Salts in the Soil (Total Solids in Water Extract Expressed in Parts per Million).*

Soil No. 1.								Soil No. 2.							
Series 1, Planted.				Series 2, Unplanted.				Series 1, Planted.				Series 2, Unplanted.			
Pot No.	Previous Moisture Content.	Total Solids.	Ratio.	Pot No.	Previous Moisture Content.	Total Solids.	Ratio.	Pot No.	Previous Moisture Content.	Total Solids.	Ratio.	Pot No.	Previous Moisture Content.	Total Solid.	Ratio.
401	15	390	—					431	15	517	—	447	15	1226	—
403	15	305	—	421	15	874	—	432	15	704	—	448	15	747	—
408	15	402	—	422	15	800	—	433	15	438	—	449	15	1510	—
Ave.	15	336	100	Ave.	15	837	100	Ave.	15	553	100	Ave.	15	1198	100
411	20	408	—					434	20	915	—				
412	20	372	—	424	20	890	—	435	20	687	—	451	20	882	—
430	20	440	—	425	20	690	—	436	20	473	—	452	20	2222	—
Ave.	20	406	120	Ave.	20	790	94	Ave.	20	691	124	Ave.	20	1550	131
415	25	329	—					437	25	760	—	453	25	1613	—
416	25	344	—	426	25	666	—	438	25	870	—	454	25	1584	—
417	25	—	—	427	25	464	—	439	25	746	—	455	25	1323	—
Ave.	25	336	91	Ave.	25	565	67	Ave.	25	792	143	Ave.	25	1507	127
418	30	366	—					440	30	941	—	456	30	1456	—
419	30	362	—	428	30	523	—	441	30	960	—	457	30	1364	—
420	30	320	—	429	30	526	—	442	30	605	—	458	30	2352	—
Ave.	30	350	95	Ave.	30	525	62	Ave.	30	835	151	Ave.	30	1724	146
								443	40	741	—	459	40	2450	—
								445	40	938	—	460	40	1467	—
								Ave.	40	863	156	Av.	40	1808	153

It would seem that the lowering of the water content as affecting the water-soluble matter depends entirely upon the types of soil used.

Nitrates.—In order to ascertain what effect the lowering of the moisture content may have upon the nitrification in the soil, the nitrates were determined on samples from all the pots after the second crop had been harvested. The samples were brought to the laboratory and the moisture and nitrate determinations were made within sixteen hours after sampling. The nitrates were determined colorimetrically by the phenol disulphonic-acid method. The results are presented in Table 6.

If a comparison of series 1 and 2 of both soils is made it will be seen that a reduction of the nitrates was caused by plant growth. The analyses also show that the nitrates are less in the planted series of soil No. 1 than in the same series of soil No. 2. This may be due to the greater amount of nitrates present in the organic clay loam before planting, there being more than necessary to satisfy the require-

ments of the plants. From Tables 3 and 4 it will be seen that a greater growth and a greater amount of total nitrogen in the crop were obtained in the organic clay loam. A decrease is found in the nitrates of the planted series due to the previous lowering of the moisture content, this decrease being more decisive in the clay loam. Under the unplanted series of both soils the results would tend to show that there has been little effect on the nitrates due to a lowering of the moisture content. A reduction may be expected in the planted series, as pots at the previous low moisture contents gave much greater growth.

TABLE 6.—*Effect of Previous Moisture Content on Nitrates in the Soil.*

Soil No. 1.								Soil No. 2.							
Series 1, Planted.				Series 2, Unplanted.				Series 1, Planted.				Series 2, Unplanted.			
Pot No.	Previous Moisture Content.	Nitrates.	Ratio.	Pot No.	Previous Moisture Content.	Nitrates.	Ratio.	Pot No.	Previous Moisture Content.	Nitrates.	Ratio.	Pot No.	Previous Moisture Content.	Nitrates.	Ratio.
	P.ct.	*p.p.m.*			*P.ct.*	*p.p.m.*			*P.ct.*	*p.p.m.*			*P.ct.*	*p.p.m.*	
401	15	14.0	—	421	15	421	—	431	15	204	—	447	15	864	—
403	15	22.0	—	422	15	183	—	432	15	140	—	448	15	688	—
408	15	21.3	—					433	15	110	—	449	15	502	—
Ave.	15	19.0	100	Ave.	15	302	100	Ave.	15	151	100	Ave.	15	685	100
411	20	16.8	—	424	20	341	—	434	20	159	—	450	20	1647	—
412	20	26.4	—	425	20	183	—	435	20	222	—	451	20	242	—
430	20	54.9	—					436	20	186	—	452	20	801	—
Ave.	20	32.7	173	Ave.	20	262	87	Ave.	20	182	132	Ave.	20	896	131
415	25	74.4	—	426	25	496	—	437	25	522	—	453	25	697	—
416	25	26.8	—	427	25	130	—	438	25	164	—	454	25	485	—
417	25	37.2	—					439	25	244	—	455	25	454	—
Ave.	25	46.1	242	Ave.	25	313	103	Ave.	25	310	205	Ave.	25	545	80
418	30	78.0	—	428	30	767	—	440	30	405	—	456	30	560	—
419	30	61.5	—	429	30	83	—	441	30	193	—	457	30	752	—
420	30	26.4	—					442	30	339	—	458	30	432	—
Ave.	30	55.3	290	Ave.	30	429	134	Ave.	30	312	205	Ave.	30	581	85
								443	40	372	—	459	40	760	—
								444	40	—	—	460	40	752	—
								445	40	185	—				
								Ave.	40	278	184	Ave.	40	756	110

Why the lowering of the moisture content in the unplanted series had no effect is hard to explain, as an aeration of the soil under the low water content would be expected to increase the nitrates, yet it is evident that the results are influenced by other factors which tend to equalize this effect.

It was thought that a study of the nitrate-producing power of the

soil might throw some light on the effect of drying soil on the nitrifying organisms of the soil. At the time the nitrates were determined in the soil, another 100-gram sample was taken, placed in a bottle, plugged with cotton, and incubated for seven days at 30° C. Nitrate determinations were then made as shown in Table 7.

A comparison of the nitrates in the soil as shown in Table 6 with the nitrates after incubation as shown in Table 7 will show that in nearly all cases denitrification has taken place. It can be seen from the tables that the variation in the samples from pots under the same treatment are too great to warrant any conclusions on the effect of lowering the moisture content on the power of the nitrifying organisms of the soil.

TABLE 7.—*Effect of Previous Moisture Content on Nitrates Produced by Incubation for Seven Days at 30° C.*

Soil No. 1.								Soil No. 2.							
Series 1, Planted.				Series 2, Unplanted.				Series 1, Planted.				Series 2, Unplanted.			
Pot No.	Previous Moisture Content.	Nitrates.	Ratio.	Pot No.	Previous Moisture Content.	Nitrates.	Ratio.	Pot No.	Previous Moisture Content	Nitrates.	Ratio	Pot No.	Previous Moisture Content.	Nitrates.	Ratio.
	P. ct.	*p. p. m.*			*P. ct.*	*p. p. m.*			*P. ct.*	*p. p. m.*			*P. ct.*	*p. p. m.*	
401	15	39	—	421	15	240	—	431	15	124	—	447	15	433	—
403	15	64	—	422	15	—	—	432	15	144	—	448	15	672	—
408	15	56	—					433	15	88	—	449	15	672	—
Ave.	15	53	100	Ave.	15	240	100	Ave.	15	118	100	Ave.	15	593	100
411	20	59	—	424	20	222	—	434	20	264	—	450	20	1152	—
412	20	48	—	425	20	184	—	435	20	176	—	451	20	370	—
430	20	34	—					436	20	96	—	452	20	704	—
Ave.	20	47	89	Ave.	20	203	84	Ave.	20	178	153	Ave.	20	778	131
415	25	37	—	426	25	200	—	437	25	200	—	453	25	608	—
416	25	34	—	427	25	160	—	438	25	144	—	454	25	576	—
417	25	40	—					439	25	168	—	455	25	336	—
Ave.	25	37	70	Ave.	25	180	75	Ave.	25	171	145	Ave.	25	507	85
418	30	50	—	428	30	21	—	440	30	352	—	456	30	480	—
419	30	34	—	429	30	84	—	441	30	276	—	457	30	572	—
420	30	50	—					442	30	360	—	458	30	448	—
Ave.	30	44	83	Ave.	30	52	20	Ave.	30	329	278	Ave.	30	500	84
								443	40	144	—	459	40	528	—
								444	40	—	—	460	40	526	—
								445	40	152	—				
								Ave.	40	148	125	Ave.	40	527	89

Potassium, Calcium, and Phosphorus.—Determinations were made of the potassium and calcium in the water extracts and of the phos-

TABLE 8.—*Effect of Previous Moisture Content on the Potassium, Calcium and Phosphorus in the Soil.*

Series 1, Planted.				Series 2, Unplanted.					
Pot No.	Previous Moisture Content.	K.	Ca.	Pot. No.	Previous Moisture Content.	K.	Ca.	P_2O_5.	Lime Required (CaO).
SOIL NO. 1									
		p.p.m.	*p.p.m.*			*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
401	15	42.2	9.0	421	15	12.0	18.5	—	
403	15	21.3	12.2	422	15	43.1	21.4	13.7	
408	15	12.6	10.1						
Ave.	15	23.3	10.4	Ave.	15	27.5	20.0	—	
411	20	30.4	7.3	424	20	14.7	21.5	—	
412	20	21.1	13.6	425	20	41.8	25.4	13.1	
430	20	11.7	11.8						
Ave.	20	21.1	10.9	Ave.	20	27.6	23.4	—	None
415	25	21.3	9.7	426	25	16.4	20.3	—	
416	25	11.6	12.1	427	25	20.3	18.8	14.6	
417	25	26.4	8.6						
Ave.	25	19.8	10.1	Ave.	25	18.3	19.6	—	
418	30	24.4	—	428	30	12.7	22.0	—	
419	30	21.4	14.6	429	30	32.3	12.6	15.0	
420	30	22.2	8.4						
Ave.	30	23.7	11.4	Ave.	30	22.5	17.3	—	
SOIL NO. 2									
431	15	28.3	13.1	447	15	74.4	23.2	14.3	1,400
432	15	19.2	17.6	448	15	84.2	27.1	—	—
433	15	62.2	9.9	449	15	60.0	29.6	—	—
Ave.	15	36.6	13.5	Ave.	15	72.6	26.6	—	—
434	20	38.4	19.0	450	20	144.3	32.7	13.4	1,100
435	20	29.6	15.1	451	20	84.4	18.6	—	—
436	20	34.3	14.6	452	20	55.8	32.3	—	—
Ave.	20	34.1	16.2	Ave.	20	91.5	27.9	—	—
437	25	14.6	17.3	453	25	104.0	27.5	18.1	1,275
438	25	29.0	13.4	454	25	41.6	19.8	—	—
439	25	38.1	20.3	455	25	111.3	25.0	—	—
Ave.	25	27.2	17.0	Ave.	25	85.6	24.0	—	—
440	30	45.2	21.0	456	30	112.0	22.8	11.8	1,200
441	30	61.0	17.2	457	30	61.8	25.9	—	—
442	30	41.4	22.8	458	30	——	24.9	—	—
Ave.	30	49.2	20.0	Ave.	30	86.9	24.5	—	—
443	40	22.9	19.4	459	40	96.6	24.8	15.2	1,075
444	40	105.2	13.4	460	40	79.0	27.0	—	—
445	40	9.2	12.3						
Ave.	40	46.4	15.0	Ave.	40	87.8	25.9	—	—

phorus in a fifth-normal nitric acid extraction of the soils. The calcium was determined by the turbidity method and the potassium by the colorimetric method of the Bureau of Soils.[3] The phosphorus

[3] Schreiner, Oswald, and Failyer, George H., Colorimetric, Turbidity and Filtration Methods Used in Soil Investigations, U. S. Dept. Agr., Bur. Soils Bul. No. 31, 1906.

was determined colorimetrically according to the method of Fraps.[4] The results are shown in Table 8.

From a study of Table 8 it may be seen that there has been very little effect due to the different moisture contents. A reduction of the potassium and the calcium was found in the planted series of soil No. 2. The phosphorus was determined in the unplanted series of both soils and no differences were found due to differences of moisture content.

It must be concluded from these data that the reduction of the moisture content has no appreciable effect on the potassium, calcium, and phosphorus in the soil.

Lime Requirement.—In order to determine whether the lowering of the moisture content had any effect on soil acidity, lime requirement determinations were made according to the method of Bizzell.[5] These results are presented in Table 8. The clay loam shows no lime requirement, the organic clay loam an average of 1,200 p.p.m. CaO. No differences are shown due to the lowering of the moisture content.

Summary of Experiment 1.

1. The drying of soil previous to planting has a beneficial effect on plant growth.

2. The factor which causes this beneficial condition due to drying is affected by the organic matter in the soil, as is shown from the results of the two soils used, which differ only in organic content.

3. The previous drying of the soil has no effect on the total nitrogen in the dry matter of the crop.

4. The water-soluble matter is increased in the clay loam with a drying out of the soil, while in the same soil with a high organic content the opposite result occurs. The organic content must be the deciding factor.

5. In the planted series of both soils a decrease in the previous moisture content has resulted in a decrease in the nitrates in the soil. In the unplanted series no effect has been found.

A denitrification was found in the soil samples when incubated at 30° C. for seven days. The great variation in the test allows no conclusions from the effects of drying the soil.

6. The drying out of the soil has little effect on the available potassium, calcium, or phosphorus in the soil.

[4] Fraps, G. S., Active Phosphoric Acid and Its Relations to the Needs of the Soil for Phosphoric Acid in Pot Experiments, Tex. Agr. Exp. Sta. Bul. No. 126, 1909 (1910).

[5] Bizzell, J. A., and Lyon, T. L., Estimation of the Lime Requirements of Soils, Journ. Indus. Engin. Chem., 5: 1011–1012, 1913.

Experiment 2. The Effect of Drying a Soil on its Physiological Condition as Measured by the Carbon Dioxid Production and Nitrification.

As a study of the effect of drying and wetting a soil on its bacterial activity, the carbon dioxid formation has been determined. A study of the effect on nitrification has also been made by determining the nitrates in the soil and its nitrifying power. It has been shown by previous investigators that the bacterial activity of the soil may be measured by the carbon dioxid production. It can not be said that this determination gives a complete measurement of the bacterial activity, yet sufficient data have been obtained to show that the effect of drying a soil on its bacterial activity may be determined in this way. As a check on the carbon dioxid determination and because of the importance of the nitrifying organisms, the nitrates and the nitrifying power were determined.

When the pots that had been kept in the field-house for two months were returned to the greenhouse, it was found that a number of them had been broken. The clay loam (soil No. 1) from six of these broken pots was transferred to new pots, and the soil brought to an optimum moisture content.

After the pots were held at an optimum moisture content for fourteen months, they were submitted to a treatment as shown in the following plan:

Pot 1. Original soil. Determinations made on wet soil.
Pot 2. The soil taken from the pot and dried in the drying room at 30–35° C. for ten days and determinations made on the dry soil.
Pot 3. Soil dried as above, but it was again brought to an optimum water content (25 per cent.) and held for sixteen days before determinations were made.
Pot 4. Treated as pot 3, but held thirty-five days before determinations were made.
Pot. 5. Treated as pot 4, but again dried and held eleven days at optimum moisture content before making determinations. (Two dryings.)
Pot 6. Treated as pot 5, but again dried and wet again fourteen days before making determinations. (Three dryings.)

Carbon Dioxid Produced on Drying and Wetting a Soil.

The method used to study the amount of carbon dioxid produced in a soil was a modification of Stoklasa.[6] A diagram and description of the apparatus is presented in figure 3.

The soil sample was well mixed and 500 grams (on dry basis) placed in the glass cylinder. The cylinders were kept in an incubator,

[6] Stoklasa, J., in Handbuch der Biochemischen Arbeitsmethoden (Alberhalden), Band 5, Teil 2, p. 869, 1912.

held at a temperature of 30° C. The air free of carbon dioxid was drawn through the soil in the cylinders, the rate of flow being regulated at "*k*" on the aspirator. By making some preliminary experiments the maximum rate of flow necessary was found. The carbon dioxid produced was measured daily for ten days, except in the case of the air-dry soil, which ceased production after the seventh day. All determinations were made in triplicate. The results for each soil are presented in Table 9.

TABLE 9.—*Daily Production of Carbon Dioxid in Parts per Million from a Soil Variously Treated as to Moisture Content.*

Sample No.	Parts per Million of Carbon Dioxid. Day. 1	2	3	4	5	6	7	8	9	10	Total.
Pot 1. Original Soil—Not Dried.											
1	546	206	76	92	120	88	52	64	198	234	1,676
2	542	216	104	104	86	162	—	152	92	140	1,598
3	546	112	116	72	74	122	0	204	72	—	1,318
Average.....	544	178	99	90	93	124	26	140	120	187	1,601
Pot 2. Soil Dried and Not Wet Again.											
1	108	8	0	68	4	0	0	—	—	—	188
2	84	16	0	46	10	0	32	0	—	—	188
3	54	108	4	40	44	30	30	0	—	—	310
Average.....	82	44	1	51	19	10	20	0	—	—	229
Pot 3. Soil Dried and Wet again for Sixteen Days.											
1	396	228	174	246	158	224	276	236	164	268	2,370
2	328	316	184	208	58	206	294	52	168	158	1,972
3	648	104	184	232	68	220	252	96	168	188	2,160
Average.....	457	216	181	228	94	217	274	128	166	205	2,166
Pot 4. Soil Dried and Wet again for Thirty-five Days.											
1	486	276	216	216	240	240	132	168	24	0	1,998
2	200	220	224	186	224	162	2	62	164	124	1,561
3	128	244	140	156	244	178	0	74	142	30	1,336
Average.....	271	247	193	186	236	193	45	101	110	53	1,635
Pot 5. Soil Dried Twice and Wet again for Eleven Days.											
1	260	554	202	168	196	166	142	166	—	—	1,854
2	1112	402	374	164	682	66	196	76	—	—	3,072
Average.....	686	478	288	166	439	116	169	121	—	—	2,463
Pot 6. Soil Dried Three Times and Wet again for Fourteen Days.											
1	414	296	186	6	400	160	100	152	216	276	2,206
2	600	284	322	262	244	204	162	110	264	190	2,642
Average.....	507	290	254	134	322	182	131	131	243	233	2,427

By a study of the tables it will be seen that the bacterial activity was greatly increased by a previous drying of the soil. In the soil that

was not wet again after drying, the bacterial activity was greatly inhibited, and after seven days the carbon dioxid production had completely stopped.

One drying of the soil greatly increases the activity over the original soil. In the soil held at an optimum moisture content for 35 days after drying the production of carbon dioxid becomes normal again, as shown by a comparison of Pots 1 and 4 (Table 9). A soil dried twice does not show a much greater activity than when dried once, while three dryings show no increase over two dryings. Evidently the factor that causes the increase is not greatly affected after the first drying of the soil.

The Effect of Drying and Wetting a Soil on the Nitrates and Nitrifying Power.

The nitrates were determined colorimetrically in a water extract of the sample by the phenol disulphonic-acid method. Samples from each pot were taken at the time the carbon dioxid determination was made, one part being used for the immediate determination of the nitrates and the other for the determination of the nitrifying power. The nitrifying power was determined by incubating the samples for seven day at 30° C. The results are shown in Table 10.

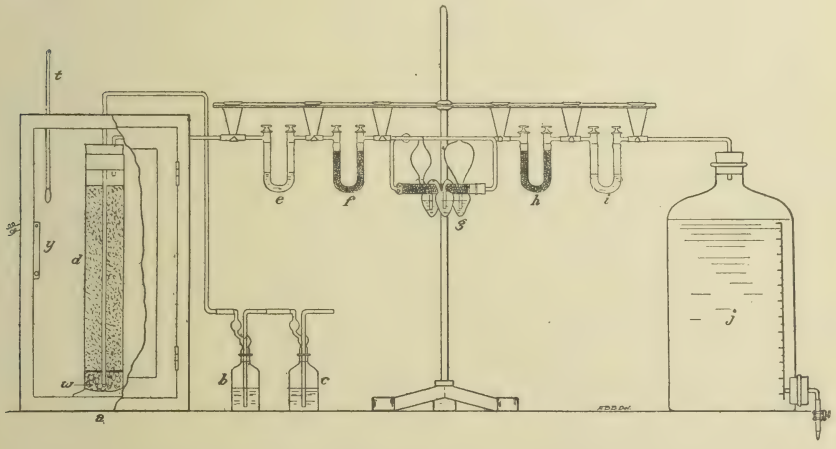

FIG. 3. Apparatus for determination of the carbon dioxid produced in a soil. Description of apparatus: *a*, Incubator; *b*, wash-bottle containing $Ba(OH)_2$; *c*, wash-bottle containing KOH; *d*, glass cylinder containing soil; *e*, U-tube containing H_2SO_4; *f*, U-tube containing $CaCl_2$; *g*, potash bulb; *h*, U-tube containing $CaCl_2$; *i*, U-tube containing H_2SO_4; *j*, aspirator bottle; *k*, stop-cock for regulating flow of air; *t*, thermometer; *w*, glass-wool in bottom of cylinder; *y*, thermostat.

TABLE 10.—*Effect of Drying and Wetting a Soil on the Nitrates and Nitrifying Power.*

	Sample No.	Parts per Million of Nitrates in:					
		Original Soil at 25 Percent Moisture Content (Pot 1).	Soil Dried Ten Days. Dry Soil (Pot 2).	Soil Dried Ten Days, Then Brought to 25 Percent Moisture Content and Held for Sixteen Days (Pot 3).	Soil Dried Ten Days, Then Brought to 25 Percent Moisture Content and Held Thirty-five Days (Pot 4).	Soil Treated as No. 4, Then Dried Ten Days, Then Wet Eleven Days (Pot 5).	Soil Treated as No. 5. Then Dried the Third Time and Wet Fourteen Days (Pot 6).
Nitrates in the Soil							
	1	140	143	117	166	264	328
	2	160	133	117	166	256	336
	Ave.	150	138	117	166	260	332
Nitrifying Power after Incubation for Seven Days at 30° C.							
Series 1,	Soil alone:						
	1	208	183	184	136	368	400
	2	200	160	162	136	384	384
	Ave.	204	172	172	136	376	392
Series 2,	Soil + 2 gr. dried blood:						
	1	192	228	208	272	400	464
	2	160	200	216	336	400	432
	Ave.	176	214	212	304	400	448
Series 3,	Soil + 0.5 gr. $(NH_4)_2CO_3$:						
	1	224	190	232	288	672	416
	2	208	228	224	304	640	416
	Ave.	216	209	228	296	656	416

First considering the effects on the nitrates, we find that the drying of the soil has greatly reduced them, and as has been previously shown also has reduced the carbon dioxid production. The rewetting of the dry soil for a period of sixteen days has further decreased the nitrification. In this sample the opposite is found in the carbon dioxid production. In the soil held moist for thirty-five days after one drying and in those previously dried twice and three times, an increase in nitrification is found. This increase corresponds with the carbon dioxid production in these samples. Why sample 3 has shown a decrease is not altogether clear.

The results from the nitrate determinations as compared with the carbon dioxid production show that the nitrification as effected by the drying of the soil is for the most part biological, but there must be factors other than biological which influence this change. These will be discussed later.

The nitrifying power of the soil was determined in three series in order to observe the effect of the addition of organic and inorganic

nitrogen on nitrification. Samples of 100 grams of soil were used in each case. The three series were as follows:

Series 1. Untreated.
Series 2. 2 grams of dried blood added to the sample.
Series 3. 0.5 gram of $(NH_4)SO_4$ added to the sample.

It will be seen from Table 10 that the addition of nitrogen either in organic or inorganic form has increased the nitrification. However, the results from each treatment as compared with the nitrates before incubation show, in the main, the same order of difference.

Considering the effect of drying of the soil on the nitrifying power, the original soil shows an increase of 54 p.p.m. when the soil has been incubated alone. Series 2 and 3 of the same sample gave an increase of 26 and 66 p.p.m. respectively. In the dry soil the nitrates are increased in about the same ratio, but here there is an error due to the wetting of the soil on incubation, and the same results are obtained as in sample 3. If the nitrifying power of the dry soil had been determined, it is very probable that no nitrifying power would have been obtained. In sample 3 there was an increase of 55, 95, and 111 p.p.m. in series 1, 2, and 3 respectively. This shows that the effect of previously drying a soil is to increase the activity of the nitrifying organisms. In sample 4 the incubation of the soil has shown a decrease, but an increase of 138 and 130 p.p.m. was found in series 2 and 3 of this sample. In the carbon dioxid determination the rewetting of the soil for a period of thirty-five days gave a result similar to the original soil. Soils dried two and three times have increased the nitrifying power over the samples dried once. From the table it can be seen that the maximum is reached at two dryings. These results would show that the activity of the nitrifying organisms is increased by a previous drying of the soil, but reaches a maximum at two dryings.

Summary of Experiment 2.

1. The bacterial activity as measured by the carbon dioxid production is increased by a previous drying of the soil.

2. The carbon dioxid production is very low in a dry soil, the production ceasing after seven days.

3. The activity is increased by two dryings, the third drying showing only very slight increase over the second.

4. A soil held moist for thirty-five days after one drying assumes its normal condition, the activity being only slightly greater than in the original soil.

5. The previous drying of the soil increases nitrification.

6. The dry soil shows a reduction in nitrates, as in the carbon dioxid production.

7. The nitrification is increased by two dryings and again in the soil dried three times.

8. The nitrifying power of the soil is increased by a previous drying.

9. The nitrifying power continues to increase with two dryings, but probably reaches its maximum at three dryings.

10. The effect of adding organic or inorganic nitrogen to the samples is shown by a marked increase in the nitrates produced. The increase in the determinations is in the same ratio as in the sample with no nitrogen added.

Discussion and Conclusions.

The foregoing results show that the drying of soil has an effect on its fertility, which results in an increased plant growth. The crop growth is increased by a previous lowering of the moisture content, but the difference in the organic content as shown in the two soils used, has influenced the changes which are produced.

In Experiment 1 there is a drying out of the soil by a lowering of the moisture content, but in no case do we have a soil completely air-dried. This experiment represents a condition that takes place in a humid region where the soil rarely reaches an air-dry condition. In a consideration of the results from Experiment 1 this must be kept in mind.

While the effects of drying on the physical changes have not been definitely studied, a discussion of the subject will necessarily include the physical factors which are acting through a change in the soil moisture.

The drying out of the soil increases the granulation, which is in the most part due to an alteration of the colloidal material. The increased granulation allows a greater amount of soluble salts to be carried in the granules, which on subsequent wetting allows a greater amount to go into solution. Referring to the results obtained on the amounts of water soluble material found in the two soils under different moisture contents, we find that the drying out of the clay loam has caused an increase in the water soluble material, while in the organic clay loam the opposite occurs. As these soils differ only in the organic content, the factor which influences the solubility of the soil constituents must be due to the difference in the organic matter of the two soils. If in the clay loam a granulation due to drying has caused a greater alteration of the colloidal material, this would allow the water greater access to the soil particle; and if the concentration of the salts

on the surface of the particle has resulted from an increased film pressure around the particle, a greater amount of soluble material will be recovered by a subsequent wetting of the soil. However, in the organic clay loam the decrease found in the soluble matter on drying would tend to show that the great amount of material soluble when the soil is held at high water content overcomes any increase that may be due to a drying of the soil.

Again, as the organic clay loam shows a lime requirement of 1,200 p.p.m. CaO, the acidity which is due to the organic matter would deflocculate the colloidal material, resulting in a less amount of surface being exposed to the solvent than in the clay loam. It has been shown by previous investigators that a soil high in organic matter has a great absorptive power. This absorptive power would increase the plant food held by the soil and result in an increase of the soluble matter when the soil was dried; but if the soil was not dried to a low enough water content to alter this absorptive power, no increase would result. The resinous and fatty material of the organic matter may surround the mineral particles and allow no greater solubility even if more soluble salts are exposed to the solvent after a drying of the soil. It has been considered by some investigators that the water-soluble material forms a colloidal film around the soil particle. On drying a soil this film will be altered and allow a greater solubility of the soluble salts. This may partly account for the increase in the water-soluble material in the clay loam when dried to a 15 percent moisture content, but in the organic clay loam it may be that the large amount of organic matter soluble would strengthen this colloidal film and a greater drying be necessary to alter the pressure of the film.

Other factors, mainly chemical, must be considered in a discussion of the effects of drying soil. The dehydration of the silicates, deoxidation of the oxids, and oxidation of many of the compounds are some of the important chemical changes which take place in the soil on drying. However, in Experiment 1 the soil has not been dried below a moisture content of 15 percent, and these factors cannot exert any marked influence on the changes produced.

The drying out of the soil causes an increase in the nitrification in the planted series, but no effect is observed in the unplanted series. Why this occurred is not clear. The biological factors that are at work here may sufficiently alter the results so as to eliminate any difference due to the changes in moisture. This will be discussed further under the results of Experiment 2.

Turning to the determinations of potassium, calcium, and phosphorus, as affected by the lowering of the moisture content, it was

found that there is no increased solubility of these elements. This would show that the beneficial effect on plant growth must be due to a great extent to an alteration of the physical condition of the soil and not to a greater amount of plant food being liberated.

The results from Experiment 1 show that the lowering of the moisture content previous to planting has a beneficial effect on plant growth. Of the changes produced in the soil, the physical, chemical, and biological factors must be considered, but in the results obtained from Experiment 1, it would seem that the change in the physical condition is the principal factor.

In Experiment 2, the results of drying a soil are studied in connection with the biological changes. The effects on the biological factors have been measured by the biochemical changes produced. This experiment differs from Experiment 1 in that the soil was dried in a drying room at a temperature of 30° C. and may be considered as air-dried.

Before discussing the effects of drying on the physiological changes produced as measured by the carbon dioxid production, it will be well to consider whether the carbon dioxid produced is a correct measure of the bacterial activity. The most important objection to this method is that the amount obtained in some cases appears to be too high to attribute to bacterial action. The chemical changes produced on drying may be partly responsible for the increase in carbon dioxid. It can not be said that all the organisms in the soil evolve carbon dioxid; but if the most important soil organisms produce carbon dioxid and if the changes produced by drying act similarly on these organisms, the measuring of the carbon dioxid production should give a relative measurement of the bacterial activity.

The results of the experiment show that a previously dried soil gives a greater bacterial activity as measured by the carbon dioxid production and nitrification in the soil. There are a number of possible reasons to be considered in a discussion of the effect of drying on the physiological condition of the soil.

It has been shown by many investigators that the organisms in the soil, except the nitrifiers, are resistant to drying. If the nitrifying organisms are destroyed on drying the soil, then the increased nitrification must be accounted for through chemical changes produced in the soil. The drying of the soil alters the colloidal material and allows a greater amount of oxygen to enter the soil. After the soil has been wet again an increase is found in the nitrates, which would be due to the induced oxidation.

If in drying a soil a greater amount of plant food is made available,

the bacteria would be able to obtain a greater supply of food. According to Greig-Smith, the drying of the soil would destroy the waxy substance surrounding the soil particle and allow the more resistant bacteria a greater food supply.

The resistance of the organisms to drying may be due to the formation of spores. As it is known that the nitrifying bacteria do not produce spores, we may consider that the decrease in the nitrifying organisms and the increase of the other organisms on drying may be due to the ability of the latter to form spores. In a discussion of the causes of the beneficial effect due to drying it is necessary to consider the hypothesis of Russell and Hutchinson. Considering that the drying of the soil is a partial sterilization, they believe that the drying of soils destroys or inhibits the action of the phagocytic organisms, and an increase in the ammonifying bacteria results, which is beneficial to the productiveness of the soil.

In an air-dried soil the hygroscopic water may be sufficient to satisfy the requirements of the bacteria. The hygroscopic water is held around the soil particle as a thin film. This film exerts a very great pressure, which, it seems, would not allow the organisms to obtain the water or the food enveloped in it; but if the bacteria themselves were included within this film, then sufficient food might be obtained.

From the results obtained in this investigation and by other workers it would seem that the increase in bacterial activity on drying a soil is not a question of bacterial numbers, but depends upon the relative resistance of the important soil organisms.

In a consideration of the effect of drying a soil on the physiological condition of the soil, no definite conclusions can be drawn until more knowledge is obtained relating to the effect on the different groups of organisms. The subject is very complex and must include many factors both chemical and physical, as, for example, an alteration of the colloidal material which would allow a greater oxidation.

The results of these studies show that the drying of soil affects the physical, chemical, and biological factors, resulting in an increased plant growth. The increased crop growth on a soil that has been previously dried is of importance to the practical question of soil management, more especially in the arid regions where the soil is often air-dried.

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PROBLEMS OF THE WHEAT CROP.[1]

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With a production of nearly a billion bushels of wheat in the United States in 1914, and a price of $1.60 per bushel at present in Chicago, it might well be supposed that the wheat crop in this country has no problems. It is the natural course, however, that expansion and depression shall follow each other in any industry, and it is exactly at the height of prosperity when we must be on our guard in preparation for the corresponding period of depression certain to follow sooner or later.

Already there are indications that wheat growing will be attempted next spring in places and under circumstances very unusual, with reckless disregard of adaptation or facilities for market. One man proposes to sow spring wheat in Virginia, another wishes to try durum wheat in Kansas. Virginia is in no sense a spring wheat State, while in Kansas the hard winter wheat probably is too well established to justify the sowing of durum wheat in spite of the premium in price of the latter, though durum is fairly well adapted in the northwestern counties.

The scarcity of good seed, also, is already being felt. This condition will become serious before spring seeding time. The temptation at prevailing prices to sell, beyond the limit of seed reserve is too great. Even to date, it appears that many have not resisted and others yet will yield, it is to be feared, before the winter is over. The probability of still higher prices for the next crop should be considered. The farmer who disposes of his reserve may be killing the goose that lays the golden egg. He should look out especially for durum wheat sead, where that wheat is adapted, as the pressure for selling it is particularly great because of the premium it commands, and there is need of a larger production of this wheat next year.

[1] During the winter months, a lecture is delivered weekly by some official of the Bureau of Plant Industry, U. S. Department of Agriculture; before the scientific staff of the Bureau. The present paper, one of these "Bureau Lectures," was presented by Mr. Carleton on February 13, 1915.

Two Classes of Problems.

The problems of the wheat industry are of two classes, agricultural problems having to do with production and commercial problems concerned with marketing, grading, transportation, etc.

Only the most important of these problems under each class will be discussed. Before doing so, attention should be called to the fact that certain problems of much moment years ago are now wholly or almost entirely solved.

Problems Already Solved.—(1) The very serious fungous enemy, the bunt of wheat, which once gave so much concern is now so easily prevented and the means of doing it so well known and thoroughly practiced that, except in certain areas, it is no longer a problem.

(2) In the past our wheat production was seriously limited by the insufficiency of spring wheat yields, but over a large part of the wheat area the existing winter varieties would not survive the winters. Now, by virtue of the introduction of hardier varieties there is only one wheat district (the northern Great Plains), a small portion of another district (the Northeastern States) and a few places of high altitude where winter wheat is not constantly successful.

(3) The establishment of winter wheat has not only directly increased the yield, but has gone far toward eliminating the problem of the chinch bug in the North Central and middle Great Plains States. Twenty to thirty years ago this insect was a constant parasite of spring wheat but rarely attacked the winter wheat in time to do any damage. Now since the production of winter wheat has become more general, especially of the earlier winter varieties, many of the present generation of farmers hardly know the insect. By the same means, the damage from rust has been greatly lessened.

Problems in the Eastern States.

Problems of production may best be discussed by geographic districts. First will be cited those of the Eastern States, or the area east of about the ninety-sixth meridian.

Earliness.—There is no locality in which earliness is not a desideratum in wheat cropping. In the East it is important as a means of escaping rust, and in some localities for escaping short periods of drought occurring frequently about heading time.

Lodging.—Lodging is a frequent defect in wheat in this district on low lands or in unusually wet localities or seasons. Varieties with strong straw are therefore needed. Accurate breaking tests have shown much variation in the strength of straw in different varieties. Turkey wheat, though resistant to rust and drought, has a weak straw.

Rust.—The rust problem, a very old one, is still with us, though as above stated, the damage from rust the country over has decreased considerably in recent years. It would no doubt be an improvement to substitute for Poole, Fultz, Currell Prolific, and other soft-kerneled wheats, a more rust-resistant variety with other qualities equally good.

Hessian Fly.—In Maryland, Pennsylvania, and adjacent areas, the Hessian fly is sometimes a very serious pest. The only means of avoiding its ravages now known is to sow late enough so that the fall swarm of flies will have come and gone without being able to deposit their eggs on the young wheat plants. Much investigation is yet needed of the relations of the Hessian fly to its host. It is not generally known that durum wheats and emmers are very resistant or practically immune to this insect, as determined by Professor F. M. Webster and his assistants. This fact in itself is of no economic advantage, as these wheats are not grown much within the range of this insect, but hybrids of these wheats with those of the common group which would resist the fly and yet possess other qualities required in the Eastern States, are quite possible. There is considerable conflict of conditions in respect to the resistance of common varieties. For example, Dawson Golden Chaff in Ontario, where it originated, is much affected, but in New York is said to be little damaged compared with other varieties.

Winter Resistance.—Winter hardiness is still a problem of some consequence in the extreme north for resisting the winter cold, and in the South for overcoming the effects of late spring frosts.

States of the Great Plains.

Drought.—Almost everywhere west of the 96th meridian, except under irrigation, the chief contention is against drought.

Drought is combated in two ways: (1) By the use of resistant or early varieties and (2) by proper methods of farming. Drought effects are avoided to a considerable degree through earliness in ripening. Here again the adoption of winter varieties has been of great advantage. Grass wheat and other spring varieties generally grown thirty years ago no doubt were at least as drought resistant as the winter wheats, but were beaten by the latter simply on the score of earliness. Varietal resistance, however, is probably the greatest factor in overcoming drought.

In the northern Plains, group adaptation in this respect has been solved, at least for a long time. The durum group has shown the highest efficiency. It only remains to adopt the best variety, which at

present appears to be Kubanka. No doubt drought resistance can yet be greatly increased by selection within the variety. Pure lines have already been established at a few points. There are possibly yet other varieties that are better. Vast subgroups of durums in India and western Asia are yet to be drawn upon. Much further investigation is needed.

In the middle and southern Plains varietal resistance is more complicated, as there is a combination of both cold and drought to overcome. Nothing tests the hardiness of a wheat to so great a degree as the strong winds of a very dry and very cold winter. For such conditions the Kharkov variety seems best adapted. Of this variety, introduced by the U. S. Department of Agriculture from eastern Kharkov, Russia, in 1900, there was a crop of 80 million bushels in Kansas alone in 1914. In Montana, which has practically been made a wheat State by the use of Kharkov, this variety yields constantly 7 or 8 bushels per acre more than any other. The better known Turkey strain apparently gives better results in a few places. The problem of winter hardiness, therefore, for some time a most serious one, is now well on the way toward complete solution. However, if winter wheat is to succeed in Minnesota and the Dakotas, much improvement is yet necessary.

Tillage.—In the matter of tillage in the Great Plains there is a real and serious problem always with us. On this subject is founded originally nearly all that is known and much more that is not known in the entire literature of so-called "dry farming." Accepted views are so soon refuted that one must have quite up-to-date information to justify him in risking a statement. Nevertheless, all dry-farming experiments to date, including especially the extensive Dry-Land Agriculture series of this Bureau, show that, as a rule, successful wheat growing in the Great Plains must follow at least one season out of three of good tillage of some kind. The tillage is best given in the form of an intertilled crop, where such a crop is possible. There is still, however, abundant opportunity for further investigation. It is noted in the experiments just referred to that there is greater response in wheat following summer tillage or an intertilled crop in the winter-wheat area than in the spring-wheat area.

Leaving Wheat Alone.—In the extreme southwestern Plains, excluding central Texas, not the least difficult problem is to convince the farmer that he should eliminate wheat entirely. In this district straight stock-raising is the only dependable occupation, and no cash crop can be expected. The toll exacted by drought, winds and distance from markets is too great for wheat to be profitable.

Western Intermountain District.

Under dry farming, the problem of tillage for combating drought in the western intermountain district is equally as important as in the Great Plains. The details of methods, however, must be different because of the occurrence of rainfall in winter instead of summer and the lack of organic matter in the soil. The problem of increasing the nitrogen content of the kernel has been a serious one in this district, but is now partially solved by the rapid introduction of Turkey wheat in dry farming. Further improvement in this line is possible.

The Alkali Problem.—Under irrigation, the great problem in the West, overshadowing all else, is the serious and growing menace of alkali. Any kind of investigation having for its object the complete amelioration of the soil and the proper handling of irrigation water, especially the drainage, is of the greatest importance.

Use of Leguminous Crops.—Leguminous crops in alternation, everywhere more or less important, are particularly so in intermountain districts where there is a great lack of soil humus. The beneficial effects of a legume on the following wheat crop are always great in the Western States. In addition to the direct effects, considerable residual effects have been noted in three successive wheat crops following one alfalfa crop.

Columbia River Basin District.

There is need of earliness and winter hardiness in this district, but two problems stand out in relief as more important than all others. These are (1) the shattering of the kernels and (2) the bunt or stinking smut of wheat.

Shattering.—In all the Pacific Coast and intermountain districts the summer dryness and the use of combined harvester thrashers, which delay the harvest, make it inevitable that all ordinary wheats will shatter seriously. For a while club wheats, which are very resistant to shattering, were largely employed, but when Turkey wheat was introduced for winter hardiness and more gluten, then the trouble began. Spillman's hybrids were made with this difficulty largely in mind. All improvements hereafter in this district must consider the problem of shattering.

Stinking Smut.—I have stated that, with one or two exceptions, the common smut of wheat is no longer a problem. In this district the wheat smut is the most serious of all problems. For some time the farmers had insisted that none of the usual treatments would prevent smut. The failures were attributed by the experiment station staff to

carelessness or inaccuracy in applying the treatments, until finally, in some experiments on a large scale, the station men had similar failures. Very careful tests were then made, and it was found that treated seed sown under the same conditions as seed purposely smutted produced plants with more smutted heads than the smutted seed. The necessary conclusion is that the soil itself is full of smut, and it is from this smut that infection commonly takes place. The problem therefore is now one of soil sanitation, and it is a very difficult one to handle. Smut has become so abundant, often infecting 15 percent or more of the crop, that the cloud of smut spores arising from the machine at thrashing time is more conspicuous than the smoke from the engine. The combined smut and dust in the dry season of 1914 was apparently the cause of numerous violent explosions in Whitman County, Washington, and adjacent territory. Over 100 separators were destroyed through such explosions in that county inside of a month, 16 in the vicinity of Pullman in one day. It happens that several dust explosions in flour mills occurred the same year. Therefore the whole subject of the manner of ignition of dust clouds and the nature of the explosions is now being investigated by the Bureau of Chemistry and the Bureau of Mines, the Office of Cereal Investigations of this department and the Washington experiment station cooperating.

The California–Arizona District.

The wheats of the California-Arizona district are of the class found in Australia, India and Turkestan. Fortunately they are usually resistant to shattering, a quality much needed in this area.

Deficiency in Gluten.—The most serious obstacle in California wheat culture is the lack of gluten in the kernel. Largely from this cause, the wheat crop has decreased to almost nothing in recent years, though at one time that State grew more wheat than any other. For many years California millers have imported one half to two thirds of all the wheat used in their mills, chiefly from the Great Plains States. Certain varieties recently introduced have more gluten, but much improvement in this line is needed.

Lack of Organic Matter in the Soil.—From the yield standpoint, the greatest need for California wheat is organic matter in the soil. In our experiments in the San Joaquin valley, the wheat yield after green rye or vetch turned under was not only far larger than in continuous cropping, but was 50 percent larger than after summer tillage. Probably no line of investigations would yield more important results in California than that of rotations and green manuring.

Commercial Problems.

The principal commercial problems are about three in number, (1) the purity of the product, (2) the grading and (3) the demands of millers and bakers.

A Single Pure Variety.—On putting the question to a friend recently: What is the first problem of the wheat crop? he said "To establish one pure variety in a locality." It is a matter of importance, probably as much so for the farmer himself as for the consumer. It may be a question for some time what variety to adopt, but when once adopted, the locality or State should proceed to gain a reputation for just that wheat and that only, until there is sufficient difference found in favor of a new variety to justify an absolute change.

Demands of the Miller and Baker.—On the other hand, we are not justified in restraining the producer from growing a better-yielding new variety merely because the miller is unacquainted with it, and may even have to change his methods or machinery to be able to handle it. The opposition of millers is therefore often a great problem. Often the miller discovers later that it is to his own advantage that the wheat has been introduced. Good examples of this condition are the hard winter and durum wheats of recent introduction into the Great Plains. The millers are now opposing the Chul wheat in California, though there is much evidence that it is a better variety in quality than the commonly grown White Australian, and far better in yield.

Grading.—This topic is presented here wholly from the standpoint of benefit to the farmer that would result from rigid grading and payment for the wheat strictly in accordance with such grading. At present at country stations there is practically one grade and poor wheat is discounted through a system of dockage. Often weight is made the basis, and, with the average price at 60 cents per bushel, prices will vary about 1 cent to each pound of loss or gain in bushel weight. This is not sufficient, as there are other qualities than weight which affect the value. The farmer, therefore, sees no difference whether he brings to the elevator first-class or third-class wheat. It would be of the greatest benefit to both the miller and farmer if a No. 2 grade, for example, were adopted as a standard, and the farmer then paid a premium for wheat grading better or a discount for wheat under No. 2 in quality. The miller would thus get what he pays for and the farmer would have before him a constant incentive to furnish better wheat.

THE EFFECT OF FREQUENT CLIPPING ON TOTAL YIELD AND COMPOSITION OF GRASSES.[1]

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A few attempts have been made to compare the quantity of grass produced when it is cut frequently and when it is allowed to mature for hay; in other words, to approximate the relative yields of pasture and meadow. The results of some experiments at the Virginia Agricultural Experiment Station are presented here as a contribution to the knowledge on the subject. Before discussing the Virginia data the writers wish to review some of the work done elsewhere.

At the Michigan station in 1894, Crozier[2] reports that one plat of orchard grass containing one-twentieth of an acre was cut seven times between April 26 and June 8. Another of the same size was cut for hay on June 8. The seven clippings gave 29 pounds of dried grass; the plat cut once produced 100 pounds. The experiment was repeated in 1896 with the plats reversed. One cut four times between May 4 and May 26 gave 60.9 pounds of dry grass; the other cut only on May 26, 112.5 pounds. A plat of timothy one by six rods in size clipped eight times between April 30 and June 24 gave 15.76 pounds of dry grass, while a similar plat cut on June 24 for hay gave 172 pounds. The percentage of crude protein in the frequently clipped timothy was 22.62, while in that cut for hay it was only 7.81.

These results have often been quoted to prove that pastures are not as profitable as meadows. There is one serious fault, however, with this experiment from the standpoint of contrasting pasturing with hay making. In each instance the clipping stopped the same day that the other plat was cut for hay. As a rule grasses and legumes that are kept grazed or cut through the spring will continue green and will grow on throughout the summer, while the aftermath on grass meadows cut for hay is slight.

In an experiment reported by Joulie[3] one plat of mixed grasses and clovers one year old cut twice gave a yield of 5.57 tons of dry hay per acre. A similar plat cut six times made a total of only 3.59 tons per

[1] Presented by Professor Carrier at the meeting of the Washington (D. C.) Section of the American Society of Agronomy, February 17, 1915.

[2] Crozier, A. A., Forage Plants and Wheat. Michigan Exp. Sta. Bul. No. 141: 130–132. 1897.

[3] Joulie, H., Journal of the Royal Agricultural Society, 18: 195.

acre, but there were 7.12 pounds more nitrogen in the hay from the acre cut six times than from the one cut twice.

Sir John Sinclair makes the following statement in his Code of Agriculture:[4]

"Land that has been used to the scythe will often produce more grass, but that will not, it is thought by some, support so much stock nor fatten them near so well as an old pasture, though it may have been better manured."

In 1908, the Virginia station, in cooperation with the Office of Forage Crop Investigations, U. S. Department of Agriculture, began some grazing experiments on permanent blue grass pastures. As a part of the work eight one-fiftieth-acre plats were staked off on a permanent blue grass sod and clipped at varying intervals with a lawn mower fitted with a basket attachment to collect the grass. These plats were intended to be used to corroborate the results obtained on some larger fields that were grazed with animals. One of these small plats was disked, one harrowed, and one was disked and harrowed. These treatments did not appear to affect the production either on the large fields or these small plats, so they are ignored in the present discussion.

The following table gives a summary of the four years' work:

In addition to the cultural treatments, an experiment was conducted in which heavy and light grazing were compared. On some of the plats the frequency of clipping was arranged in imitation of this heavy and light grazing. One plat was clipped every week, three every ten days, two every twenty days, one every thirty days, and one was allowed to mature and was cut once each season, usually in July, for hay. After the first season, the dried grass was sampled and a protein determination made of each clipping by the chemical department of the Virginia station. The original plan was followed for five years before the work was changed. This gave data on weights and protein content of all the samples of grass for four years.

TABLE I.—*Total Yield of Air-dry Hay for Four years from 1/50 Acre Plats Cut at Various Intervals, with the Percentage of Protein and the Total Protein Content in Each Lot.*

Number of Plats.	Frequency of Cutting.	Air-dry Substance.	Average Protein Content.	Total Protein.
		Pounds.	*Percent.*	*Pounds.*
1	Every 7 days	111.34	15.58	17.36
3	" 10 "	112.93	14.84	16.76
2	" 20 "	114.93	14.43	16.58
1	" 30 "	138.45	12.67	17.93
1	Once a year	197.25	8.25	16.28

[4] Sinclair, Sir John, Code of Agriculture, First American Edition, p. 281. 1818.

In the spring of 1913 the plan of the experiment was changed to a test of fertilizers. The plat that was clipped every seven days and the one that was cut once a year were left unfertilized, but the frequency of cutting of these two plats was reversed. The one which previously had been cut once each year was cut every week, and the one that had been frequently clipped was allowed to mature for hay. There were also three unfertilized plats in the series which were cut every fourteen days. The results from these five plats for the year are given in Table 2.

TABLE 2.—*Yield of Air-dry Grass in 1913 from 1/50 Acre Plats Clipped at Various Intervals, with the Percentage of Protein and the Total Protein Content in Each Lot.*

Number of Plats	Frequency of Cutting.	Air-dry Substance.	Average Protein Content.	Total Protein.
		Pounds.	*Percent.*	*Pounds.*
1	Every 7 days	18.13	15.22	2.76
3	" 14 "	17.75	14.31	2.54
1	Once a year	30.5	7.00	2.14

From these experiments it seems safe to draw the following conclusions for permanent blue grass sod:

1. The total yield of dry matter varies inversely with the number of times it is cut during the growing season.

2. The percentage of protein in grass decreases as the grass matures.

3. The decrease in percentage of protein when the grass is allowed to mature is sufficient to more than counterbalance the increase in weight of dry matter.

4. The increase in weight of mature grass over frequent clippings must be fiber and other nitrogen-free substance.

5. The cost of hay making would probably offset the gain in carbohydrates in the case of blue grass so that land utilized as a permanent pasture should be more profitable than it would be as a permanent meadow.

It may be of interest to state that the botanical character of the herbage varied greatly with the frequency of the cutting. On the plats that were frequently clipped blue grass, redtop and white clover predominated, while on those that were cut less frequently, especially on the one that was cut but once a year, these tame grasses gave way to rank-growing weeds such as wild carrot, paspalums, yarrow, white top, etc. This undoubtedly had much to do with the amounts of protein produced.

AGRONOMIC AFFAIRS.

MEETINGS OF THE SOCIETY.

The annual meeting of the American Society of Agronomy, as previously announced, will be held August 9 and 10, 1915, at Berkeley, Cal., on the campus of the University of California. On the same days, the Society for the Promotion of Agricultural Science and the American Farm-Management Association will hold their annual meetings. Two joint sessions of the three organizations just named are planned, as well as two or more separate sessions. On the three days following (August 11–13), the Association of Agricultural Colleges and Experiment Stations will meet at Berkeley, while the meeting of the Association for the Advancement of Science and its affiliated societies will occur the week previous (August 2–7) in San Francisco. These meetings and the Panama-Pacific International Exposition should attract a large numer of agronomic workers to the City of the Golden Gate during the first two weeks in August.

Several members of the American Farm-Management Association are planning to meet in Chicago, St. Paul or Omaha and make the trip to the Berkeley meeting together, stopping at points of agricultural interest along the way. Members of the American Society of Agronomy who desire to join a party of this nature will be welcomed. Those who are interested should write the secretary of the American Farm-Management Association, Mr. G. A. Billings, Office of Farm Management, U. S. Dept. of Agr., Washington, D. C., stating their preference as to routes.

On July 14–16, a sectional meeting of the society will be held at Mandan, N. Dak., in connection with the annual meeting of the Great Plains Cooperative Association. The latter organization is composed of those engaged in experimental work in the Great Plains region, either under State or Federal auspices. It is hoped that a full quota of agronomic workers in the Great Plains States and from the Prairie Provinces of Canada will be in attendance. Papers for presentation at this meeting should be limited to topics of interest in the Great Plains.

A call for the titles of papers for presentation at these meetings was sent to all members in February. As yet, very few titles have been forwarded to the secretary. Members with suitable material for papers are urged to send in the titles at an early date, so that the programs, particularly of the annual meeting at San Francisco, may be printed early enough for distribution to the members of the society by mail.

BRIEF ARTICLES FOR PUBLICATION.

The editorial board believes that the members of the American Society of Agronomy should make more frequent use of the JOURNAL for the publication of brief articles. Incidental phases of an investigation which frequently have little bearing on the matter in hand are often of much interest and importance to other workers, yet they escape publicity because there seems to be no place for them in official channels of publication. Likewise, notes on lines of work which the investigator is obliged to abandon for one reason or another before the completion of the experiment often lie buried in official files because of their incompleteness, yet their suggestive value to others may be great. It is in the presentation of material of this kind, in the publication of brief descriptions of methods, and along similar lines that the JOURNAL should render greater service. Articles of this nature should be brief, clear and concise, ranging in length from a single paragraph to about five typewritten pages. Let us have more brief papers!

ANNUAL DUES OF MEMBERS.

Notice of annual dues has been sent to all members by the treasurer. To save expense to the society and to prevent the treasurer's duties from becoming a burden, members are urged to remit promptly. Those who are still in arrears for 1914 lapse automatically on April 1. The names of lapsed members will be published in the May–June number of the JOURNAL, unless they apply for reinstatement and remit dues before the date of its publication.

MEMBERSHIP CHANGES.

The membership of the society as reported in the previous issue of the JOURNAL was 422. Since that time, 19 new members have been added and 3 members have resigned, making a net membership at this date of 438. Some memberships will lapse according to the constitution on March 31, but with the natural increase the total should re-

main well above 400. The names and addresses of new members, names of members resigned, and changes of address which have been reported are as follows:

New Members.

Billings, G. A., Farm Management, U. S. Dept. Agr., Washington, D. C.
Brown, E. B., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Burdick, R. T., University of Vermont, Burlington, Vt.
Ellison, A. D., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Garland, John J., Agronomy Building, Univ. of Wis., Madison, Wis.
Hansen, Dan, Experiment Farm, Huntley, Mont.
Hendry, Geo. W., College of Agriculture, Berkeley, Cal.
Hill, H. H., Experiment Station, Blacksburg, Va.
Jones, S. C., Experiment Station, Purdue Univ., LaFayette, Ind.
Kinzy, Grover, Agricultural College, College Park, Md.
McCall, M. C., Lind, Wash.
Merkle, Fred G., Route 3, Box 8, Agricultural College, Amherst, Mass.
Moomaw, Leroy, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Neff, C. E., 1312 Bass Ave., Columbia, Mo.
Richardson, A. M., Waterville, Wash.
Thompson, James, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Walster, H. L., College of Agriculture, Madison, Wis.
Watson, E. B., 17 Budd Hall, Univ. of Cal., Berkeley, Cal.
Young, M. H., Agricultural College, College Station, Texas.

Members Resigned.

Clinton, L. A.
Lloyd, W. A.
Potter, H. B.

Addresses Changed.

Brown, C. B., Garden City Substation, Garden City, Kans.
Engle, C. C., College of Agriculture, New Brunswick, N. J.
Gaines, E. F., Bussey Institution, Forest Hills, Mass.
Gieseker, L. F., Experiment Station, Bozeman, Mont.
Grantham, Geo. M., Experiment Station, East Lansing, Mich.
Hanger, W. E., 133 West Ninth Ave., Columbus, Ohio.
Hendrick, H. B., Office Exp. Stations, U. S. Dept. Agr., Washington, D. C.
Kinnaird, R. A., Normal School, Maryville, Mo.
Klein, Millard A., Barnard Apt. 3, Omaha, Nebr.
Lill, J. G., Arkansas Valley Substation, Rocky Ford, Colo.
Lods, E. A., Demonstrator, Cowansville, Quebec, Canada.
Tinsley, J. D., 507 Union Station, Galveston, Texas.
Tucker, Geo. M., Office Exp. Stations, U. S. Dept. Agr., Washington, D. C.
Umberger, H. J. C., Extension Division, Agr. College, Manhattan, Kans.
Whiting, Albert L., 504 East Chalmers St., Champaign, Ill.
Woodworth, C. M., Agricultural Hall, Univ. of Wis., Madison, Wis.
Zook, L. L., North Platte Substation, North Platte, Nebr.

NEW BOOKS.

The Chemistry of Agriculture for Students and Farmers. By CHARLES W. STODDART, PH.D., Professor of Agricultural Chemistry, Pennsylvania State College. Lea & Febiger (Philadelphia and New York), 1915. 8 vo. Pages 347 + vi; figs. 83; plates 1.

It seems to be almost inevitable that writers and teachers of the fundamental sciences as applied to agriculture and home economics go to the one extreme of presenting the subject in the pedagogical form of the science itself, with an undesirable minimum of illustrations from the field of daily life, or to the other extreme of presenting a series of unrelated facts concerning the scientific properties of the substances dealt with in major courses of instruction in these vocational branches. To those who hold that instruction in agricultural chemistry should consist in the presentation of a series of facts concerning the chemical constitution and properties of the compounds concerned in plant and animal growth and of the physiological changes which they undergo, with no serious attempt at an understanding of their relationships or the principles underlying these changes, Dr. Stoddart's new book will prove thoroughly satisfactory.

The author states that the book is written to meet the need "for a text on general agricultural chemistry which will cover the field briefly, in a logical manner, giving only the facts, and not consisting of a disconnected series of quotations and tables from the very extended literature of the subject."

The arrangement which seems to the author to be "logical" presents in Part I a discussion of the plant, starting with the germination of the seed and the growth of the plant, followed by a discussion of the composition of plant compounds and of farm crops; in Part II, the factors in plant growth, including the air, the soil, fertilizers, insecticides and fungicides, and the gas engine; and in Part III, the chemistry of animal life, including animal physiology, food and digestion, and milk and dairy products. This arrangement involves certain difficulties, such as the necessary discussion of changes in compounds during germination and growth before the nature of the compounds themselves has been explained, the inclusion of insecticides and fungicides and the gas engine as factors in plant growth, a rather inadequate presentation of the relation of the composition of plants to their use by animals as food, etc.

The belief of the author that the book is "sufficiently elementary to make it of value to any intelligent reader" even though he be without previous training in botany, chemistry, geology and physics, seems

hardly justified from the standpoint of chemistry at least, by the inclusion of a large number of complex graphic formulas with no explanation of their meaning and of frequent allusions to acid, aldehyde and ketone groups, esters, etc., with no explanation of the meaning of these terms or of their relationships.

The text is commendably free from inaccuracies of statement, but it is to be regretted that a few such glaring ones should have appeared as "the properties (of oils) are the same whether the oils are so-called mineral oils, . . . or are vegetable oils, . . . or are volatile oils also found in plants" (page 72) and "proteins occur in the granular or crystalline form" (page 38).

The illustrations, while many of them are of common farm scenes and hence do not illustrate particular principles of agricultural chemistry, are excellent, being unusually sharp, clear and well-reproduced, and add much to the attractiveness of the book. The book itself is well made mechanically and attractively bound.

While the reviewer does not personally approve of the fundamental conception of the method of instruction in agricultural chemistry presented in the book, he welcomes its clear and accurate presentation of the present opinions of our best agricultural chemists concerning the chemical compounds and physiological changes involved in plant and animal growth as a distinct addition to the elementary literature of this subject.—R. W. T.

NOTES AND NEWS.

Dr. Charles E. Bessey, for the past thirty years professor of botany at the University of Nebraska and one of the best-known botanists in America, died at his home in Lincoln, Nebr., February 25, 1915, in his seventy-first year. The value of a training in economic botany received under Dr. Bessey will be attested by many agronomists.

E. A. Bryan, for many years president of the Washington State College, has resigned, effective January 1, 1916.

Dr. George N. Coffey, for the past several years in charge of soil fertility investigations at the Ohio station, is now assistant State leader in county agent work in Illinois, with headquarters at Urbana. It is understood that Dr. Coffey will devote the major portion of his time to soil problems.

E. F. Gaines, cerealist of the Washington station, is on leave of absence till July 1 to pursue graduate study in plant breeding at Bussey Institution, Forest Hills, Mass.

L. F. Gieseker, who has been pursuing graduate studies in soils and plant breeding at Cornell University since September, 1913, has returned to his former position with the Montana college and station.

W. E. Hanger, formerly of the Maryland Agricultural College, has been a member of the teaching force in field crop production at Ohio State University since January 1.

H. B. Hendrick, formerly extension assistant in agronomy at the Kentucky college, is now assistant in agricultural education in the Office of Experiment Stations, U. S. Department of Agriculture.

T. A. Kiesselbach, agronomist of the Nebraska station, spent the month of February in Washington, D. C. During his stay, he devoted most of his time to a study of the literature of the water requirements of plants, in the library of the U. S. Department of Agriculture.

L. A. Moorhouse, recently agronomist of the Manitoba college of agriculture, is now in charge of a study of sugar-beet production as a farm enterprise, in the Office of Farm Management, U. S. Department of Agriculture.

W. R. Skelly has been appointed an instructor in farm crops and botany at Purdue University.

Dr. Charles W. Stoddart, chemist of the Pennsylvania college and station, is the author of a new book entitled "The Chemistry of Agriculture for Students and Farmers," published by Lea and Febiger.

H. J. C. Umberger, formerly of the office of cereal investigations, U. S. Department of Agriculture, and for the past three years engaged in farming at Hymer, Kans., on March 1 became demonstation supervisor in the extension division of the Kansas college, with headquarters at Manhattan.

Recent appointments in the office of forage crop investigations, U. S. Department of Agriculture, include H. R. Reed, by transfer from the Philippine Department of Agriculture, assigned to the field station at Bard, Cal., and Leroy Moomaw of the Missouri college of agriculture, assigned to the Judith Basin substation, Moccasin, Mont.

The following changes in field-station assignments have recently been made in the office of dry-land agriculture, U. S. Department of Agriculture: A. J. Ogaard, from Williston, N. Dak., to Hettinger, N. Dak., as superintendent of substation, *vice* H. C. McKinstry, resigned to engage in ranching in Wyoming; J. T. Sarvis from Ardmore, S. Dak., to Mandan, N. Dak., as agronomist of the Northern Great

Plains Field Station; W. M. Osborn from North Platte, Nebr., to a new station at Lawton, Okla.; L. L. Zook, by transfer from the office of corn investigations, to North Platte, Nebr.; C. B. Brown, from Dalhart, Texas, to Garden City, Kans., *vice* J. G. Lill, transferred to the office of sugar-beet investigations; and L. N. Jensen, from Woodward, Okla., to Amarillo, Texas, *vice* C. W. Burmeister, transferred to the office of markets.

Cereal Conference in California.

An interstate conference on investigations of cereals to be held in California, has been announced for May 25–28, 1915. This is a conference on investigations in all phases of cereal research, at which such topics will be discussed as (1) Problems of Pacific Coast wheat production; (2) improvement of barley for the Pacific Coast; (3) problems in cereal smuts; (4) grading, milling, malting, and baking; (5) weed control in cereal production; (6) tillage and crop rotation; and (7) insect enemies of cereals. It is expected that Dr. F. Kølpin Ravn, Professor of Plant Pathology at the Royal Agricultural College, Copenhagen, Denmark, will be present. The conference will meet at Merced, Cal., Tuesday, May 25, for a field inspection of cereals in the San Joaquin Valley; on May 26 the conference proper will begin at the University of California, Berkeley; on May 27 the program will be continued at the University Farm, Davis, including an inspection of the farm; and on May 28 the plant introduction garden at Chico and the cereal field station at Biggs will be inspected. Agronomists and others interested in cereal production are cordially invited. Those who expect to attend should notify Dr. J. W. Gilmore, University of California, Berkeley, Cal., or Mr. M. A. Carleton, Department of Agriculture, Washington, D. C.

A New Local Section in Iowa.

A local section of the American Society of Agronomy was organized at Iowa State College, Ames, Iowa, on February 9, 1915, with a total membership of 28, 19 of whom are members of the general organization. Meetings will be held on the second Tuesday of each month during the college year. The officers for 1915 are as follows: *President,* Ross L. Bancroft; *Secretary,* R. A. Needham; and *Treasurer,* J. A. Krall.

Meeting of the Washington, D. C., Section.

The seventh meeting of the Washington section was held at the Cosmos Club, Washington, D. C., on Wednesday evening, February 17, 1915. About 55 members and guests were present. Mr. G. W. Morgan discussed certain features of the uniform experiments conducted by the Office of Dry-Land Agriculture at numerous stations in the Great Plains, under the title "Comparison of Spring and Fall Plowing in the Great Plains Area." He presented figures and charts to show that at nine stations in this area from Akron, Colo., northward, in experiments conducted from two to six years, the increase in moisture content from harvest to seeding time the following spring was greater on spring-plowed than on fall-plowed plats, and that the yield was also greater from spring plowing. At three stations in Kansas and Texas, the results slightly favored fall plowing. In all cases, the plats were cropped continuously to spring wheat.

Mr. Lyman Carrier presented a paper entitled "The Effect of Frequent Clipping on the Total Yield and Composition of Grasses." This paper appears elsewhere in this issue.

In an illustrated paper on "Some Features of Rice Culture," Mr. Chas. E. Chambliss discussed interestingly the features in which the culture of rice resembles and those in which it differs from the culture of the other cereals. He stated that the water applied to rice in the Louisiana and Texas area and in California amounted to about 2.35 and 4.65 acre-feet respectively, but that the total water used by the crop was practically the same in both areas, because of the greater rainfall on the Gulf Coast. Mr. Chambliss spoke briefly of the experiments in rice culture conducted cooperatively by the Louisiana station and the U. S. Department of Agriculture at Crowley, La., and of the recent development in rice culture in California. In the latter State the first commercial planting was made in 1912, while in 1914 rice was grown on 16,000 acres, the resulting crop having a value of $800,000.

The evening closed with a social hour, with refreshments.

COMING EVENTS.

Under this caption it is proposed to keep standing a schedule of coming meetings of various organizations more or less closely connected with agronomy. Secretaries of such bodies are invited to furnish information regarding their meetings.

American Society of Agronomy.

Special meeting, Mandan, N. Dak., July 14–16, 1915, in connection with the meetings of the Great Plains Cooperative Association.

Annual meeting, University of California, Berkeley, Cal., August 9–10, 1915. (In connection with meeting of Assoc. Agric. Coll. and Exp. Stations.)

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

San Francisco, Cal., August 2–7, 1915.

AMERICAN ASSOCIATION OF AGRICULTURAL COLLEGE EDITORS.

Madison, Wis., June, 1915.

AMERICAN GENETIC ASSOCIATION.

San Francisco, Cal., August 2–5, 1915.

ASSOCIATION OF AGRICULTURAL COLLEGES AND EXPERIMENT STATIONS.

University of California, Berkeley, Cal., August 11–13, 1915.

GREAT PLAINS COOPERATIVE ASSOCIATION.

Mandan, N. Dak., July 14–16, 1915.

LOCAL SECTIONS.

CORNELL UNIVERSITY AND EXPERIMENT STATION.

President, Millard A. Klein.
Secretary, ...

IOWA STATE COLLEGE AND EXPERIMENT STATION.

President, Ross L. Bancroft.
Secretary, R. A. Needham.

KANSAS AGRICULTURAL COLLEGE AND EXPERIMENT STATION.

President, W. M. Jardine.
Secretary-Treasurer, C. C. Cunningham.

WASHINGTON, D. C.

President, H. N. Vinall.
Secretary-Treasurer, P. V. Cardon.

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SULFUR AND PERMANENT SOIL FERTILITY IN IOWA.[1]

P. E. BROWN AND E. H. KELLOGG,

IOWA AGRICULTURAL EXPERIMENT STATION, AMES, IOWA.

INTRODUCTION.

Sulfur has long been known to be one of the essential plant food constituents. It has always been believed, however, that there was sufficient present in all soils for the optimum growth of crops. This assumption has been very largely based on Wolff's analyses[2] of the ashes of various crops, which showed the presence of very small amounts of sulfur.

The recent work of many investigators has demonstrated, however, that the amount of sulfur in plant materials as determined in the ash is, in most cases, entirely too low. There is a considerable loss of sulfur in the process of igniting, and the amount found in the ash, therefore, may be a very small part of that originally present in the plant tissues.

INVESTIGATIONS IN WISCONSIN.

Hart and Peterson[3] have summarized the work of previous investigators and have themselves made analyses of numerous farm products for sulfur content, using the Osborne method. A comparison of their results with the earlier analyses of Wolff showed definitely that by the old method a large portion of the total sulfur in all plants was volatilized in the ignition, in some instances as much

[1] Contribution from the Soil Chemistry and Bacteriology Laboratory, Iowa Agricultural Experiment Station. Received for publication February 16, 1915.

[2] Wolff's Aschen Analysen.

[3] Hart, E. B., and Peterson, W. H., Sulfur Requirements of Farm Crops in Relation to Soil and Air Supply, Wis. Agr. Expt. Sta. Research Bul. 14, 1911.

as 90 per cent being lost. They also showed that the sulfur content of crops or the amount of this element removed from the soil by the growth of most farm crops was much greater than had previously been supposed.

It is evident, therefore, that the amount of sulfur present in soils may be of considerable moment in soil fertility studies and that some soils may be deficient in this element to such an extent that crops may suffer. Indeed, the evidence of several experiments tends to show that sulfur may be the limiting factor of growth in certain cases just as nitrogen, phosphorus and potassium are so often found to be.

Hart and Peterson analyzed several soils for total sulfur. They found that normal soils in Wisconsin were relatively poor in this constituent, containing from 0.033 to 0.140 percent of sulfur trioxide (SO_3). Most of them, however, contained less than 0.1 percent. This amount was practically the same as the content of phosphorus pentoxide (P_2O_5) in the soils. They showed also that soils cropped for 50 to 60 years and either unmanured or receiving but slight applications during that period lost on the average 40 percent of the sulfur trioxide originally present, as determined by comparison with virgin soils. Where farm manure was applied in regular and fairly liberal amounts, however, the sulfur content of the soil was maintained and even increased. After a careful consideration of the data secured at Rothamsted on the loss of sulfur in drainage water and the addition of that element to the soil in the precipitation they conclude that losses of sulfur from the soil by drainage and cropping are larger than can be met by the amount brought down in the rain. Some carrier of sulfur, such as farm manure, superphosphate, ammonium sulfate, sulfate of potassium, or gypsum must be applied to soils, therefore, if they are to be maintained in a permanently fertile condition.

Investigations in Kentucky.

The analyses of numerous Kentucky soils given in a bulletin by Shedd[4] received after this work was under way confirm the earlier work in Wisconsin. Constant cultivation without manuring was again shown to lead to a loss of sulfur from the soil and the amounts of sulfur present were usually found to be smaller than the amounts of phosphorus. As a rule, the better agricultural areas showed a higher sulfur as well as a greater phosphorus content, leading to the conclusion that there is a close relation between the sulfur and phos-

[4] Shedd, O. M., The Sulfur Content of Some Typical Kentucky Soils, Ky. Agr. Expt. Sta. Bul. 174, 1913.

phorus content of soils and their agricultural value. The conclusion was reached also that the addition of sulfur in some form is essential if soils are to be kept fertile permanently.

This bulletin also contains a fairly complete list of the experiments which have been conducted in other countries with the use of sulfur in various forms. These foreign investigations have shown that many crops may be benefited by the application of sulfur to the soil, whether it is applied in the form of sulfate which is directly available as plant food or whether it is added as free sulfur. The application in the latter form is usually made for the purpose of remedying certain fungous or other diseases of plants. The beneficial effects, however, have been much greater than could be expected from phorus content of soils and their agricultural value. The conclusion has therefore been reached that the use of the sulfur was of value because of the actual addition of an essential plant food constituent.

So far as the authors are aware, no further studies of sulfur in soils except those mentioned have been conducted in this country. It is hoped that the work reported here will add to our knowledge of the subject and supplement the Wisconsin and Kentucky results to such an extent that the question of sulfur fertilization as a necessity for permanent agriculture may receive more widespread consideration and definite principles may be reached which shall be of more than local application.

The Sulfur Content of Iowa Soils.

Accepting the evidence mentioned above that ordinary farm crops remove considerable amounts of sulfur from the soil, the question of the supply of sulfur in the soil becomes very important. If soils are not rich in this constituent and materials containing it are not applied, it is obvious that sooner or later a deficiency must occur and crops will suffer for lack of a proper supply of sulfur. Analyses of some typical Iowa soils have been made, therefore, in order to ascertain the amount of sulfur present and consequently the need for some material containing this element for the maintenance of permanent soil fertility in Iowa. Some of the samples of soil, the plant food content of which is reported in a recent publication,[5] were analyzed for their sulfur content. These samples were used for the reason that they had been carefully chosen as representative of the large soil areas of the State. Thus there were samples of the Mis-

[5] Brown, P. E., The Fertility in Iowa Soils, Iowa Agr. Expt. Sta. Bul. No. 150, 1914.

souri loess, the Mississippi loess, the Southern Iowa loess, the Wisconsin drift, and the Iowan drift soils. These samples were taken at three depths, as follows: 0 to 6⅔ inches representing the surface soil; 6⅔ to 20 inches representing the subsurface soil; and 20 to 40 inches, representing the subsoil.

Method of Determination.

The sodium peroxide fusion method proposed by Osborne and worked out by Hart and Peterson, with one important modification which will be described later, was employed in this work. The method was carried out as follows:

Ten-gram quantities of the soils, air-dried and ground, were weighed out in nickel crucibles, moistened with water and about 10 grams of a weighed 20-gram portion of sodium peroxide added. This was then thoroughly mixed with the soil and the crucible placed over an alcohol flame and heated gently until the mass was dry. The mixture was then stirred until it was quite white. The remainder of the peroxide was then added and the crucible was covered and heated over a strong flame for about an hour. After cooling, the fused mass was removed from the crucible with hot water and acidified with HCl. About 10 c.c. of HCl was then added and the mixture heated on a steam bath until the fused mass was entirely broken up and all the chlorine gas was expelled from the solution. The mixture was then transferred to a 500 c.c. volumetric flask and made up to volume.

After settling, an aliquot of 300 c.c. was drawn off and the iron and aluminum present were removed by the addition of ammonium hydroxide and filtering. The filtrate was made slightly acid by the addition of a few drops of HCl. This removal of iron and aluminum was apparently quite essential for the obtaining of satisfactory results. When these materials were not removed, much difficulty was experienced in securing the agreement of duplicate determinations and the sulfate precipitates were apt to be contaminated with iron and aluminum compounds. The previous descriptions of the method do not mention the need for the removal of iron and aluminum, but this work indicates that little dependence could be placed upon results secured in their presence. They should be removed, therefore, before the precipitation of the sulfates. The extent of the interference of these constituents undoubtedly depends upon the amounts in which they occur in the soils tested.

It was found necessary also that only a slight excess of acid be introduced before the addition of the barium chloride, as a large

amount of HCl prevented to a considerable extent the precipitation of the barium sulfate. This precipitation was then performed as usual by the addition of 10 c.c. of a hot 10 percent $BaCl_2$ solution to the boiling filtrate obtained as described above, allowing this to stand for several hours on the hot plate and then for twenty-four hours, filtering, washing, drying, heating over the blast and weighing. According to this method, no difficultiy was experienced in obtaining an agreement of duplicate determinations and the results were quite satisfactory.

Results of Determinations.

The sulfate content of the soils was detemined by shaking 100 grams of the soils with 200 c.c. of water in the shaking machine for

Table 1.—*The Total Sulfur and Sulfate Content of Various Iowa Soils Expressed in Pounds per 2,000,000 Pounds of Surface Soil, per 4,000,000 Pounds of Subsurface Soil, and per 6,000,000 Pounds of Subsoil.*

Soil No.	County.	Surface Soil.[1]		Subsurface Soil.[2]		Subsoil.[3]	
		Sulfur as Sulfate.	Total Sulfur.	Sulfur as Sulfate.	Total Sulfur.	Sulfur as Sulfate.	Total Sulfur.
			Missouri Loess Soils.				
4	Shelby	38	751	Trace	1,090	Trace	1,299
15	Monona	34	802	Trace	1,396	108	1,566
20	Woodbury	34	753	Trace	1,268	Trace	1,449
108	Page	Trace	716	112	1,204	96	1,140
			Mississippi Loess Soils.				
67	Muscatine	36	441	Trace	812	Trace	1,002
77	Des Moines	60	803	184	1,052	156	1,056
124	Poweshiek	60	847	176	1,372	126	1,326
127	Johnson	74	787	72	1,058	Trace	804
			Southern Iowa Loess Soils.				
83	Monroe	82	760	96	1,054	138	953
89	Appanoose	70	574	156	1,140	210	1,146
94	Decatur	46	863	72	916	Trace	831
102	Ringgold	62	886	100	1,310	Trace	1,292
			Wisconsin Drift Soils.				
30	Clay	94	902	152	1,546	Trace	1,263
36	Kossuth	40	1,110	100	1,510	114	1,392
A	Story	—	1,130	—	—	—	—
B	Story	—	892	—	—	—	—
C	Story	—	750	—	—	—	—
D	Story	—	846	—	—	—	—
			Iowan Drift Soils.				
42	Cerro Gordo	112	1,233	188	1,312	144	792
45	Floyd	52	1,094	—	1,438	102	795
46	Bremer	54	647	76	1,062	Trace	747
57	Delaware	56	599	100	1,016	108	1,087

[1] Depth of sampling 0 to 6⅔ inches.

[2] Depth of sampling 6⅔ to 20 inches.

[3] Depth of sampling 20 to 40 inches.

seven hours, filtering and precipitating with barium chloride and determining the sulfates by the use of the sulfur photometer. This method was devised by the writers after a long series of experiments reported elsewhere.[6] The total sulfur content and the sulfate content of the soils from the various soil areas are given in Table 1. These results were obtained by calculating the sulfur in pounds present per 2,000,000 pounds of surface soil, per 4,000,000 pounds of subsurface soil, and per 6,000,000 pounds of subsoil.

Variations in Sulfur Content.

An examination of Table 1 will show that there was a considerable variation in the content of sulfates in different soils of the same type. This is to be expected when it is recalled that sulfates are constantly being produced in the soil from the insoluble compounds and that these sulfates are partly taken up by plants and partly leached out of the soil. The amount present in the soil at any one time depends, therefore, on several factors, among which are the rate of production or the efficiency of the sulfofying bacteria in the soil, the crops grown and their sulfur content, and the drainage from the soil. No conclusions can be drawn, therefore, from the amounts of sulfates present in these soils and the results have not been averaged.

There was some variation also in the total sulfur content of the various soils within the same areas. Thus in Table 1, under the analyses of the Mississippi loess soils, No. 67 contained only 441 pounds of sulfur per acre in the surface soil, while the other samples showed 803, 847 and 787 pounds per acre respectively. Similarly among the Southern Iowa loess samples, No. 89 contained 574 pounds of sulfur per acre, while the other three samples of Southern Iowa loess soils showed a content of 760, 863 and 886 pounds per acre.

This variation in sulfur content might be expected, for Shedd has pointed out that there was much less sulfur in cultivated unmanured soils than in virgin soils. It is quite evident that not only would soils of different origin vary widely in sulfur content, but also soils of the same origin differentiated by different treatments or under different weather conditions would contain quite different amounts of sulfur. Averages have been struck for the total sulfur content of the soils in the five large soil areas in the State. While these averages would undoubtedly be altered somewhat by including the results of the analyses of a large number of samples, it is felt that they show fairly accurately the amount of sulfur in these typical soil areas.

[6] Brown, P. E., and Kellogg, E. H., Sulfofication in Soils, Proc. Iowa Acad. of Science, 21 : 7.

Sulfur and Phosphorus Content.

These average results appear in Table 2, together with the average phosphorus content obtained by the analyses of a large number of typical soils, the results of which have been published.

Table 2.—*Average Sulfur and Phosphorus Content of Representative Iowa Soils, Expressed in Pounds per Acre in 2,000,000 Pounds of Surface Soil, 4,000,000 Pounds of Subsurface Soil, and 6,000,000 Pounds of Subsoil.*

Soil.	Sulfur			Phosphorus.		
	Surface.	Subsurface.	Subsoil.	Surface.	Subsurface.	Subsoil.
Missouri Loess	755	1,239	1,363	1,538	2,697	3,892
Mississippi Loess	719	1,073	1,047	1,361	2,204	3,003
Southern Iowa Loess	770	1,105	1,055	1,368	2,089	2,972
Wisconsin Drift	938	1,528	1,327	1,395	2,217	3,253
Iowan Drift	893	1,207	855	1,289	2,207	2,889

It will be noted in Table 2 that there was not a wide variation in the total sulfur present in the surface soils in the various soil areas. The Wisconsin drift was the richest in sulfur, the Iowan drift next, then the southern Iowa loess, then the Missouri loess, while the Mississippi loess was the lowest in this element. As a general rule, the drift soils appeared to be higher than the loess soils in sulfur, at least in the surface 6⅔ inches. In the subsurface the same relations did not exist. The Mississippi loess was again the lowest in sulfur, but the Missouri loess was higher than the southern Iowa loess or the Iowan drift soil. Again the Wisconsin drift soil showed the largest amount of sulfur.

In the subsoil further variations between the different soils in regard to their sulfur content occurred. The Missouri loess here showed the largest amount, slightly larger even than the Wisconsin drift. The Mississippi loess and the Southern Iowa loess were lower than these two and about the same in sulfur content. The subsoil of the Iowan drift contained the smallest amount of sulfur. It is apparent, therefore, that at the surface the drift soils contained more sulfur than the loess soils. At the lower depths, however, the Iowan drift decreased rapidly in amount of sulfur present. The Wisconsin drift also decreased, but in that soil area the amount present in the subsoil was still greater than that in the subsoils under most of the other areas.

Comparing these results with the average amounts of phosphorus in these large soil areas, it will be seen that there was nearly twice as much phosphorus as sulfur in the surface soils of some of the

large soil areas. In other cases, the differences were not so great. The phosphorus content in the subsurface soils and subsoils was very much greater than the sulfur content. It has been believed that phosphorus was the element most apt to be lacking in Iowa soils and that systems of permanent agriculture should all center around it. These results show that there is much less sulfur than phosphorus in the soils, and hence they indicate that all systems of permanent agriculture in Iowa which leave the sulfur out of account would be incomplete and insufficient.

Sulfur and Phosphorus in Farm Crops.

It will be well to consider here the relative amounts of sulfur and phosphorus in the common farm crops and to calculate the depletion of soils in these constituents by the growth of ordinary crops. These figures are given in Table 3. The percentage of sulfur in the crops was obtained from the analyses by Hart and Peterson and the number of pounds removed from the soil by maximum crops was calculated in each case.

Table 3.—*Pounds of Sulfur and of Phosphorus Removed per Acre by Maximum Crops.*

Crop.	Maximum Yield.	Sulfur Content.	Phosphorus Content.
		Pounds.	*Pounds.*
Corn, grain	100 Bu.	8.5	17
Corn, stover	3 T.	7.5	6
Total for corn crop	——	16.0	23
Wheat, grain	50 Bu.	4.3	12
Wheat, straw	2.5 T.	5.9	4
Total for wheat crop	——	10.2	16
Oats, grain	100 Bu.	6.8	11
Oats, straw	2.5 T.	9.7	5
Total for oat crop	——	16.5	16
Barley, grain	60 Bu.	4.0	10
Barley, straw	1.5 T.	4.4	2
Total for barley crop	——	8.4	12
Potatoes	400 Bu.	32.6	17
Alfalfa hay	8 T.	45.9	36
Timothy hay	4 T.	15.2	12
Clover hay	4 T.	13.1	20

A brief examination of Table 3 shows that there are quite considerable amounts of sulfur removed by one maximum crop. Thus 8 tons of alfalfa hay take out 45.9 pounds of sulfur, and 400 bushels of potatoes, 32.6 pounds of sulfur. The amounts of sulfur removed are in most cases about the same or slightly less than the phosphorus taken out. Comparing these results with the results of the analyses

of the soils, it will be seen that there is enough sulfur in the Mississippi loess soil, the poorest in sulfur, to grow 44 maximum crops of corn, 71 maximum crops of wheat, 22 crops of 400 bushels of potatoes, or 15 crops of 8 tons of alfalfa hay. In the other soils enough is present for a slightly larger number of crops. Of course, if the corn stover and small grain straw are not removed from the soil and the grain crop alone is to be considered, the "life" of the soil is much greater, but it is evident that there is not enough to keep crops well supplied indefinitely. Furthermore, the subsurface soils and subsoils are not rich in sulfur and there is no opportunity of supplying this element, therefore, from the deeper soil layers.

Addition of Sulfur in Rain Water and Loss by Drainage.

There is, of course, an addition of sulfur to all humid soils in the rain water. Hart and Peterson have discussed this point. Although their observations in Wisconsin were not complete, they concluded that the amount of sulfur added to humid soils in the United States in the rain water would be about the same as in England, and they accepted Hall's estimate of 6.8 to 7.2 pounds of sulfur per acre annually. They pointed out also the fact that the loss of sulfur in the drainage water may more than compensate for the addition in the precipitation. Hall's results were again cited, showing a loss of 20 pounds of sulfur per acre annually from the unmanured plots and 34 to 88 pounds from the manured plots in the Broadbalk fields at Rothamsted. These results were obtained on the assumption of an annual drainage of 10 inches of water.

It is evident upon comparing these figures that there is more than three times as much sulfur lost from the manured plots by drainage than is brought down in the rain.

Realizing the fact, however, that these figures should hardly be considered applicable to all climates and to all soils, the authors concur in the conservative statement of Hart and Peterson that "loss by drainage at least equals and probably exceeds the amount brought to the soils from the atmosphere in the humid regions of America."

In the absence of positive data for Iowa conditions, the length of "life" of Iowa soils from the sulfur standpoint has been determined without regard either to the addition of sulfur in the rain water or to the loss of sulfates in the drainage water.

It must be understood, therefore, that the following discussion which deals with the return of sulfur to the soils, is applicable only *if the loss of sulfur by drainage and the addition in the precipitation*

are equal. If the loss by drainage is much greater, then additional applications of sulfur-bearing materials above those recommended would be required.

Maintaining the Sulfur Supply.

It is evident from the foregoing that some means must be employed if the sulfur content of the soils is to be indefinitely maintained. The most practical means of returning sulfur to the soil would seem to be by the use of manures. Green manures would be of no use, as they merely return the sulfur which they remove from the soil. Results reported elsewhere have shown that in ordinary soils the sulfur in horse manure and cow manure is readily oxidized to sulfates. Analyses of these materials have been made, and upon calculation it is found that applications of 10 tons of horse manure and cow manure return to the soil 12.28 and 16.02 pounds of sulfur, respectively. This 10-ton application is the quantity of manure generally used.

It is apparent that such a quantity applied once in the rotation would not return sufficient sulfur for one maximum crop of corn, much less for the two crops of corn, one of oats and one of clover which make up the regular four-year rotation. In order to supply enough sulfur for these four crops in maximum yields, it would require an application of about 40 tons of cow manure or 50 tons of horse manure once every four years, or a yearly application of 10 to 12 tons. For normal yields, which are about three fourths of the maximum, 8 to 9 tons of manure applied annually would be required to keep up the sulfur content in the soil.

These figures are based on the assumption that the corn stover and oats straw are removed from the land and form a part of the manure, and they are applicable, therefore, under systems of live-stock farming. If the stover and straw are left on the soil and only the grain removed as in grain farming, 20 to 30 tons of manure per acre once in the rotation would maintain the sulfur supply in the soil for maximum yields. In grain farming, however, no manure is produced. If the sulfur is supplied in this way the manure must be purchased, which would prove very expensive, if it were possible.

In general, then, it is apparent that the production of manure on a live-stock farm is quite insufficient to keep up the sulfur supply in the soil. Unless manure is purchased and large amounts of commercial feeds are used, some other sulfur-containing material must be employed if the soil is to be kept permanently fertile. In grain farming,

either a large amount of manure or some sulfur fertilizer must be bought and applied, or sooner or later crops will suffer from a lack of this element.

The purchase of manure is rarely possible, and hence in practically all cases commercial sulfur-containing materials must be used. There are several sulfur fertilizers which may be employed. In the first place, if acid phosphate is used to maintain the phosphorus supply in the soil, the sulfate present in it as $CaSO_4$ will suffice to keep up the sulfur content. The fact that acid phosphate does contain calcium sulfate and that a deficiency in sulfur may occur in soils is an additional reason to suggest the use of acid phosphate on soils.

Calcium sulfate or gypsum as such may be applied to soils. Indeed, it often has been used and has proved a valuable fertilizer. It has been believed that the beneficial effect of this material was due to a stimulating action, but its value has probably been due in part at least to the need for sulfur in the particular soil studied.

Kainit is a fertilizer which is often applied to soils to supply potassium. It contains sulfates and hence the value of the material on some soils may be due in part to the sulfur added. Ammonium sulfate is frequently used on soils as a nitrogenous fertilizer, but its sulfur content makes it of value also as a sulfur fertilizer. It is not believed, however, that kainit or ammonium sulfate should be generally employed on Iowa soils, as deficiencies in potassium rarely occur and a lack of nitrogen may be more cheaply supplied by growing a well-inoculated crop of a legume and turning it under as green manure.

In grain farming, therefore, where manure is not produced, the sulfur supply in the soil must be maintained by the use of acid phosphate or gypsum, and inasmuch as phosphorus must be applied in some form in such cases, it seems probable that acid phosphate would be the logical material to employ, as it would maintain both the phosphorus and sulfur supply in the soil.

Conclusions.

The results of this work lead to the following conclusions, some of which are undoubtedly more widely applicable than just to Iowa conditions:

Iowa soils are shown to contain small amounts of total sulfur, much less on the average than the phosphorus content in the case of each of the large soil areas.

Some of the sulfur removed from the soil by crops may be re-

turned by the use of manure. Generally speaking, the amount of manure produced on a live-stock farm is, however, quite insufficient to keep up the sulfur content of soils. Unless manure is purchased or large amounts of commercial feeds are used, commercial sulfur-containing fertilizers must ultimately be applied to maintain Iowa soils permanently fertile. In grain farming, where there is no production of manure, all the necessary sulfur must eventually be supplied by the use of sulfur fertilizers, or sooner or later crops will suffer for a lack of this element.

Inasmuch as phosphorus also must be applied to Iowa soils to keep them permanently fertile and acid phosphate supplies not only phosphorus but also sulfur, it seems probable that this material may be a very logical fertilizer to employ.

THE PROTOTYPE OF THE CULTIVATED SORGHUMS.[1]

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The problem of determining the wild ancestor of a cultivated plant which has become profoundly modified under domestication through long periods of time is complex and difficult. Furthermore, there is no criterion as to what constitutes adequate proof, other than the consensus of botanical opinion.

In a general way it may be assumed that the range of diversity disclosed by the varieties of a cultivated plant is greatest in those which have been cultivated for a very long period of time, or over a very wide area of territory, or both.

Where no historical record of the origin of a cultivated plant is preserved—as is the case with all of our really important food plants, most of which have probably been cultivated many thousands of years—recourse must necessarily be had to other types of evidence. First to be considered are the facts of morphology. Where critical comparison of a cultivated plant with its nearest wild relatives discloses but one of the latter in which there is essential agreement in structural characteristics, the logical conclusion is that the one is the ancestral form of the other. Conversely, if any really different character occurs in the one not present in the other, there must remain serious doubt of their genetic identity.

Second, there must be some coincidence between the area of dispersal of the wild plant and that of its supposedly domesticated descendants. In all probability every plant domesticated in prehistoric times was first cultivated in some part of the region where it grew naturally. The subsequent distribution, which might in time extend to widely distant regions, must not be incompatible with its supposed point of origin.

Third, and very cogent, is evidence that discloses sexual affinity. If the assumed wild ancestor crosses readily with its supposed cultivated derivatives, and especially if such crossing be spontaneous, it is strong proof of their close genetic relation. Conversely, if such crossing does not take place spontaneously, or is difficult to achieve artificially, the plants can scarcely be considered conspecific.

[1] Received for publication February 15, 1915.

The actual demonstration of the ancestral relations of a wild plant to its cultivated derivatives can perhaps be secured only by again breeding the latter from the former. Such a demonstration has never been fully carried out in the case of any cultivated plant, and perhaps is impossible of realization. Most of the profound changes that have taken place in domesticated plants are in all probability of the nature of mutations, and have arisen at intervals during a long period of time and under very diverse conditions. If there be any definite relations between mutation and environmental conditions, the enormous difficulty of duplicating these is apparent.

It is questionable if any other crop plant shows as great an assortment of widely differing forms as do the cultivated sorghums. Thirty or more of these have been described in the past as distinct species, but there is general agreement among modern botanists that the sweet sorghums, the broom corns, and the numerous grain-producing plants, including durra, kafir, kaoliang, and the jowar of India, are all varieties of a single species profoundly modified during domestication. As regards the genetic relationship of these cultivated varieties to the nearest wild relatives, there is less agreement of opinion.

The problem seems to have been examined first by De Candolle[2] He considers that the cultivated sorghums represent two botanical species, *Holcus sorghum* L. and *Holcus saccharatus* L. although he states that botanists are not agreed among themselves. His idea of the first species is stated to be represented by a figure in Host[3] of a dense-panicled sorghum resembling Orange sorgo, and of the latter by another figure in the same work of a loose-panicled plant, which is otherwise very similar.

De Candolle's summary of the facts then known led him to conclude that both of the supposed species were originally native to Africa, but the data concerning wild forms were admittedly vague and unsatisfactory. Apparently he did not even consider the possibility of *Andropogon halepensis* (L.) Brot. being the original wild plant, though this species must have been well known to him.

The problem was later attacked by Hackel,[4] whose main conclusions may be summarized as follows:

1. Sorghum can not be maintained as a genus distinct from *Andropogon*, as held by Persoon, Trinius, Nees, and Bentham and Hooker. The characters relied upon by different authors have been, first, the

[2] De Candolle, A., L'Origine des Plantes Cultivées, pp. 305–308, 1883.

[3] Host, N. T., Icones et Descriptiones Graminum Austriacorum, vol. 4, plates 2 and 4 respectively. 1809.

[4] Hackel, E., Die Kultivirten Sorghum-Formen und ihre Abstammung. Engler's Botanische Jahrbücher, Band 7, pp. 115–126. 1886.

paniculate rather than spicate inflorescence, but this is the same in sorghum and such undoubted species of *Andropogon* as *A. punctatus* Roxb., *A. saccharoides* Swartz and *A. micranthus* Kunth; second, the ciliate lodicules, but these are smooth in the American species of sorghum; third, the coriaceous lemmas, but such occur in *Andropogon squarrosus* L. f., and are lacking in *Sorghum canescens* Hack.; finally, the character of disarticulate rachis relied upon by Trinius does not hold in one cultivated variety of sorghum. As a section or subgenus *Sorghum* may be maintained as a fairly natural group of 12 wild species, 6 in the Old World, 5 in the New, and 1 common to both hemispheres.

2. The wild species nearest to the cultivated sorghums is *Andropogon halepensis* (L.) Brot. (*A. arundinaceus* Scop.), with four varieties; namely, *propinquus, effusus, virgatus* and *aethiopicus*. All of these drop their spikelets at maturity by the disarticulation of the pedicel, but individual plants differ considerably in the readiness with which the spikelets are shed.

3. Cultivated sorghums, with the exception of a single variety, do not drop their spikelets at maturity. This is to be looked upon as the result of selection, largely unconscious, as only those grains are saved by the husbandman which have not fallen. In course of time, this would eliminate all but those with persistent spikelets. A similar contrast is seen by comparing rye, wheat, oats, millet, or rice each with its nearest wild relative; the seeds shatter in the wild forms, but are held firmly in the cultivated plants.

4. The spikelets of the cultivated sorghums differ from those of *Andropogon halepensis* essentially only in the larger grains, in the development of which the glumes have also kept pace.

5. *Andropogon halepensis* (L.) Brot. and all the cultivated sorghums constitute but a single botanical species, for which the name *Andropogon arundinaceus* Scop. is adopted.[5] In this may be distinguished two subspecies; namely, *spontaneus,* to which belong the wild varieties *genuinus, propinquus, effusus, virgatus* and *aethiopicus;* and *cerealis,* under which are included all the numerous cultivated varieties.

"But with this systematic nomenclature I combine a deeper meaning: *I express thereby the conviction that all cultivated forms of sorghum have descended from varieties of Andropogon arundinaceus spontaneus.* I say from varieties, because it appears to me evident that the same variety is not the

[5] In Hackel's monograph of the genus *Andropogon* published in 1889 (De Candolle Monogr. Phan. 6: pp. 500–520) he uses the name *Andropogon sorghum* L. for the collective species; subspecies *halepensis* in place of *spontaneus;* and subspecies *sativus* in place of *cerealis.*

basis for all. What is more, I believe that *H. arundinaceus genuinus* (*A. halepensis* sensu stricto) was not at all concerned in it, but that it was much more the varieties *effusus, virgatus,* and *aethiopicus,* perhaps also *propinquus,* which furnished the starting point. The influence of the variety *virgatus* shows itself perhaps in the cultivated forms with elongated panicles (var. *Usorum, caudatus*); from the var. *aethiopicus,* the forms resembling *saccharatus* could have developed; from these, through the shortening of the panicle branches, those corresponding to *vulgaris;* through further rounding and enlarging of the grains, the var. *cernuus,* and so on. Nevertheless, at present no more than vague guesses can be made as to the parent stem of the cultivated forms; the closer investigation of the cultivated and wild forms, especially in Central Africa, will certainly shed more light upon it." (Translation.)

But he also writes,

"My investigations have led me to a conclusion which diverges so widely from all heretofore expressed that I dare not hope to see it accepted without question by the majority of botanists."

Nevertheless, no serious attempt seems to have been made to controvert his conclusions. They have been accepted by most agronomic writers, who in general speak of *Andropogon halepensis* as the wild ancestor of the cultivated sorghums. On the other hand, botanists have as a rule maintained *A. halepensis* (*genuinus*) as distinct from *A. sorghum.* Ascherson and Schweinfurth[6] definitely express disagreement with Hackel's opinion that *A. halepensis* and *A. sorghum* represent but one species.

Koernicke,[7] in a paper published previous to that of Hackel but in the same year reached the conclusion that *Andropogon halepensis* is the ancestor of the cultivated sorghums. Apparently he was familiar only with true *A. halepensis,* that is, the plant with rootstocks.

In the culture of Johnson grass and numerous sorghums in the United States, facts have accumulated which render necessary a critical review of Hackel's conclusions.

Johnson grass (*Andropogon halepensis*) was first grown in the United States about 1830, the seed having been brought from Turkey.[8] It may now be found persisting spontaneously over much of the area south of latitude 37°, the southern boundary of Virginia and Kentucky westward to Arizona and California. In many places it has occupied the land so thoroughly as to be a serious menace to the cultivation of other plants.

Broom-corn sorghums were grown in Virginia and probably else-

[6] Ascherson and Graebner, Synopsis der Mitteleuropaischen Flora, Band 2, Abt. 1, p. 45. 1898.

[7] Koernicke and Werner, Handbuch des Getreidebaues, 1: 300. 1885.

[8] Ball, C. R., Johnson Grass: Report of Investigations Made During the Season of 1901, U. S. Dept. Agr., Bur. Plant Indus. Bul. 11, p. 7. 1902.

where in colonial days. The first sweet sorghum, Chinese sorgo, was introduced into the United States in 1853 and was followed a few years later by the introduction of numerous South African forms. Since that time sorghums have been generally cultivated in the United States. In recent years their culture has received great impetus due to the fact that they are especially adapted to the semiarid region of the Great Plains from South Dakota to Texas.

One other sorghum needs special mention. Drummond in 1835 collected a plant growing spontaneously at New Orleans which was named *Sorghum drummondii* by Nees, and later *Andropogon sorghum* var. *drummondii* by Hackel. From the description as well as authentic specimens preserved at Kew there can be no doubt that this represents the plant called "chicken corn" in Louisiana and Mississippi. Until about 1895 it seems to have been abundant in these two States, maintaining itself vigorously and often producing large volunteer crops that were cut for hay. This variety is annual and therefore could maintain itself only by producing seed. In recent years it has become almost extinct, probably due to the work of the sorghum midge. This variety is particularly interesting on account of the aggressive manner in which it maintained itself. It undoubtedly came from Africa as various specimens from the Niger River region agree exactly.

Briefly, it appears that Johnson grass became well established 50 years or more ago in many parts of the Southern States. In Louisiana and Mississippi it grew spontaneously in many places along with the earlier introduced chicken corn. When other sorghums were cultivated they must often have grown where Johnson grass occurred. Indeed for the past twenty years at least, sorghum fields infested with Johnson grass have been common enough wherever Johnson grass grows. Yet in all this time no one has recorded any natural hybrid between Johnson grass and any sorghum. Such a hybrid with chicken corn might easily be overlooked because the inflorescences of the two are similar, but a cross with any of the larger broad-leaved sorghums would certainly have been noticeable. In response to a general letter of inquiry in September, 1912, to experiment station agronomists, every one answered that he had never seen nor heard of such a hybrid.

In the last two years, however, natural hybrids between Johnson grass and sorghum have been found. The first were detected on a farm near Chillicothe, Texas, in September, 1912, and further plants were collected at the same place in 1913. Individuals vary widely,

but all agree in having rather broad leaves and most of them have rootstocks. In some the panicles are rather loose as in Johnson grass, in others more dense.

In 1910 at Lockhart, Texas, a supposed hybrid of Johnson grass and sorghum was found by Mr. A. D. Mebane. Mr. Mebane did not plant the seed, however, but upon request generously presented it to the Department of Agriculture in 1913.

One other instance of natural hybridization has been found at Pilot Point, Texas, the parents being Johnson grass and Honey sorgo.

It is evident therefore that while natural Johnson grass hybrids do occur they are very rare, not at all what would be expected if Johnson grass were the immediate ancestor of the sorghum. Incidentally it may be noted that all these hybrids have been found in Texas, in a region of relatively low rainfall.

One other line of negative evidence is worth considering. If the cultivated sorghums were derived from Johnson grass, it would be but reasonable to expect an occasional reversion to the production of rootstocks by sorghums, but after much search no such form has been found. Under favorable conditions sorghum plants will live two seasons or perhaps more, but apparently they never show any tendency to produce rootstocks. Particularly instructive in this respect is the nearly extinct chicken corn, which has been growing practically wild for eighty years. If any of its individuals had acquired the rootstock habit, they would survive the general extinction of this variety, but none such have been found.

On the other hand Johnson grass shows no tendency to lose its rootstock habit. The valuable character of this grass in producing heavy yields of hay is largely offset by its ability to persist as a weed due to its rootstock habit. On this account a vigorous search was instituted to see if any Johnson grass plants might be found without rootstocks, but without success.

From these facts it must be concluded that the rootstock character is deep seated and one to be given great weight in classification.

The recent introduction into the United States of two wild or semi-wild annual sorghums, namely, Sudan grass and Tunis grass, has furnished a series of facts which throws additional light on the subject; indeed, clears up the major difficulties of the whole matter. The former of these was secured from Khartum and the latter from Dr. Trabut in Algeria, who, however, writes that he obtained the seed from Egypt. These two grasses closely resemble Johnson grass, but lack the rootstocks. From the start both of these grasses, especially the former, have readily and abundantly produced spontaneous hybrids with any sorghums near which they were grown.

Sudan grass therefore contrasts strongly with Johnson grass in two characters, one morphological (its lack of rootstocks) and the other physiological (its ability to cross readily with the sorghums). The conclusion is certainly evident that Sudan grass is far more closely related to sorghums than is Johnson grass.

Hackel's studies and conclusions were based largely on the characters displayed by the flowers and seeds. Apparently he had no data relative to hybridization, and in his argument he practically ignores the rootstock character. His work was necessarily mainly with herbarium material, and this often did not show the underground characters. The classification he adopted is in outline as follows:

Andropogon Sorghum.
A. Subspecies *halepensis.*
var. *genuinus.*
var. *effusus.*
var. *propinquus.*
var. *virgatus.*
var. *aethiopicus.*
B. Subspecies *sativus.*
var. *drummondii.*
(Numerous cultivated varieties.)

Hackel knew that Johnson grass, variety *genuinus,* possessed rootstocks and that in *virgatus* and *æthiopicus* these organs were absent. About the other two there was great doubt. It is now known that rootstocks are produced by *propinquus* and that in *effusus* they do not occur.

Recent studies of the herbarium material preserved in Berlin, Kew, and in the United States, together with culture studies of all the forms obtainable, have led to the conclusion that *Andropogon halepensis* and *Andropogon sorghum* represent two botanical species, distinguished definitely by the presence of rootstocks in the former and their absence in the latter. Based on this distinction *Andropogon halepensis* occurs in the countries about the Mediterranean eastward through southern Asia to China, the Philippines and many of the other Malaysian islands. Through this wide area occur seven distinguishable subspecies. *Andropogon sorghum,* characterized by the absence of rootstocks, is apparently confined to Africa, occurring generally south of the Sahara Desert and in Madagascar and the neighboring islands. In this region occur eleven or more wild races or subspecies from some of which it appears that the negroes gather the seed in time of food scarcity.

In a previous paper[9] the writer has thus classified the known forms:

Andropogon halepensis (L.) Brot. Southern Europe, northern Africa, Asia Minor eastward to northern India.
Andropogon halepensis anatherus Piper. Same range as preceding.
Andropogon halepensis leiostachys Hack. Corsica.
Andropogon halepensis miliformis (Schultes) Piper. India, Ceylon.
Andropogon halepensis muticus Hack. India.
Andropogon halepensis siamensis Piper. Siam.
Andropogon halepensis propinquus (Kunth) Hack. Philippines, Borneo, Buru, China.

There is no reason to believe that any of the above plants have ever been cultivated for the grain or that the cultivated sorghums have been directly derived from them. Hackel suggested that *propinquus* might be a starting point for some of the cultivated sorghums, but from the fact that it possesses rootstocks and has very small florets while the few varieties of sorghum cultivated by the Filipinos have very large florets, the suggestion seems quite untenable.

Andropogon sorghum (L.) Brot. was based originally on cultivated varieties, particularly the one commonly cultivated in southern Europe with yellow grains and smooth glumes and an Arabian durra with white grains and villous glumes. Of the cultivated plant there are very numerous varieties. Wild forms occurring in Africa represent at least eleven races or subspecies, as follows:

Andropogon sorghum exiguus (Forsk.) Piper. Egypt, Nubia.
Andropogon sorghum eichengeri Piper. German East Africa.
Andropogon sorghum sudanensis Piper. Sudan.
Andropogon sorghum verticilliflorus (Steud.) Piper. Madagascar, Reunion, Bourbon, German East Africa, Natal, Rhodesia.
Andropogon sorghum effusus Hackel. Nigeria, Kamerun, Spanish Guinea, Togo, Congo River. Introduced in Brazil and Venezuela.
Andropogon sorghum vogelianus Piper. Mouth of Niger River.
Andropogon sorghum abyssinicus Piper. Gallabat.
Andropogon sorghum cordofanus (Hochst.) Piper. Kordofan.
Andropogon sorghum hewisoni Piper. Sennaar.
Andropogon sorghum niloticus Stapf. Sudan.
Andropogon sorghum drummondii (Nees) Hack. Nigeria, French West Africa. Introduced in United States.

It is quite certain that more wild races or subspecies of *Andropogon sorghum* will be disclosed by further botanical exploration in Africa. Until these are better known it is somewhat hazardous to predict which of the wild races have given rise to the cultivated sorghums. If we

[9] Piper, Charles V., *Andropogon halepensis* and *Andropogon sorghum*, Proc. Biological Soc. of Washington, 28: 25–44. 1915.

assume that no wild form would be cultivated unless it already possessed food value when growing wild, it would apparently be necessary to discard from consideration *exiguus*, *abyssinicus*, *eichengeri*, and *sudanensis*. All of these except *abyssinicus* have much narrower leaf blades than any cultivated sorghums; all except *sudanensis* shatter very readily; and in none is the grain as large as in other wild races.

Hewisoni might well be the ancestor of the durras, which it resembles more closely than does any other wild race known. The durras are largely confined to Egypt and Sudan whence they have spread northeastward into Asia, but apparently not into South Africa until very recently.

Drummondii is so similar to cultivated varieties that Hackel associated it with them. It might easily be the ancestor of such varieties as Orange and kafir.

. *Niloticus* possesses in a wild form grains large enough to be used as food. It does not, however, suggest to us any cultivated varieties.

Vogelianus looks like a promising grass to cultivate for grain. Kirk collected specimens below Mazzaro on the Zambesi River on which he noted "grows in damp places 4–8 feet high. Fruit eaten by the people in times of famine."

Verticilliflorus does not impress one as having good possibilities as a grain crop. It is practically the only race in southern Africa, the region where some of the best grain sorghums have originated. On a specimen collected by Busse at Kwa-Wasiri, German East Africa, he has the following interesting note:

"Diese Pflanze ist im gabi Sud der cultivierte sorghum sehr ähnlich, nur durftiger als dass; vielleicht die durch aberwilderung wiedergewonnen Urform von Andropogon sorghum?"

There is yet too much to be learned about the wild sorghums to determine with any assurance which are the actual prototypes of the cultivated sorghums. It seems perfectly clear, however, that *Andropogon halepensis* and its subspecies as above defined are not at all concerned. It appears equally clear that not all of the wild races of *Andropogon sorghum* can be considered as probable ancestors of the cultivated varieties. The ones most likely to belong in this category are *hewisoni, niloticus, drummondii* and possibly *effusus* and *verticilliflorus*. The last two races as at present understood are very variable and perhaps each name stands for several distinct plants. The problem of the wild ancestors of the cultivated sorghums is now so narrowed that it is reasonable to hope that the details may in the near future be definitely determined.

A METHOD FOR TESTING THE BREAKING STRENGTH OF STRAW.[1]

B. C. Helmick.

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In breeding work with small grains it may be desirable to select, among other characters, for strength of straw. To do this, it is necessary to have some apparatus with which one can obtain a fairly accurate test of relative strength. The method used in the Plant Breeding Department at Cornell University has been as follows:

"The method employed was to cut the pieces of straw to a length of eight centimeters, using the part nearest the root. This piece was then placed across an augur hole in a board, the hole being 5.5 centimeters in diameter. A tiny bucket was then suspended from the middle point of the piece of straw by means of a hook made from wire about one millimeter in diameter. Shot was then poured into the bucket at an uniform rate until the straw broke. A very fine shot, about No. 12, was used. The combined weight of the bucket and the shot required in order to break the straw was considered as the breaking strength of the straw."[2]

This of course was only an arbitrary standard, but since the same part of the culm was used each time, it gave results which expressed satisfactorily the relative strength of straw. To obtain good results with this apparatus, however, the operator must be able to pour the shot at the same rate for all tests, and to stop the instant the straw breaks. The fact that the shot cannot always be poured at the same rate introduces certain errors when this method is used.

In order to obtain an apparatus to obviate such errors, a machine was made which works on the same principle but which is automatic in its action. The shot falls into the bucket from a funnel at a uniform rate and the flow is automatically stopped when the straw breaks. This apparatus is shown in Plate I, Fig. 1.

This machine consists of a stand 14 inches long by 8 inches wide by 12 inches high with a flat board top. Through this top a hole is cut 4¾ inches long by 2 inches wide. One inch from the bottom of the stand and parallel to the top is placed a platform hinged at one end.

[1] Paper No. 51, Department of Plant Breeding, Cornell University, Ithaca, New York. Received for publication February 10, 1915.

[2] Leighty, C. E., Variation and Correlation in Oats (*Avena sativa*). Cornell Agr. Exp. Sta. Memoir No. 4, p. 84, 85. 1914.

At the other end, this platform is fastened to the cut-off by a wire in such a manner that when the bucket of shot drops on the platform it

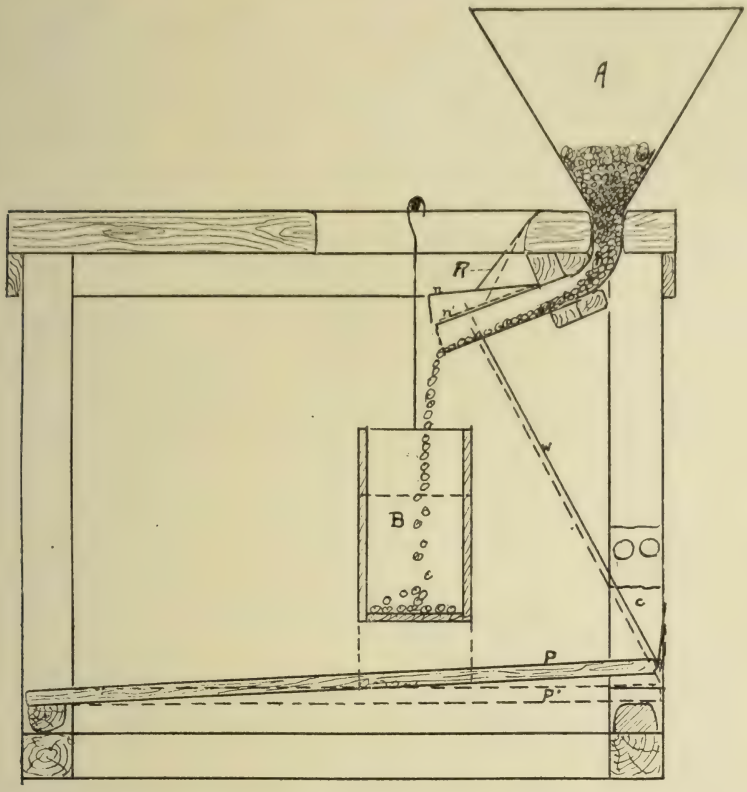

FIG. 4. Cross section of apparatus for determining the breaking strength of straw.

automatically shuts off the flow of shot. The hopper is a 6-inch glass funnel with the stem bent at an angle of about 80 degrees. Over this is fitted a tin spout, the lower end of which is filed smooth so that the hinged cut-off will fit closely when drawn down by the platform, to which it is attached by a wire. The cut-off is held open and the platform held up by rubber bands, although springs might be more desirable. A sectional view of the apparatus is shown in fig. 4.

The machine operates as follows: The straw is placed in position and the bucket suspended on it; the platform is then released by pressing back the spring at *c* (Fig. 4) and the rubber band *R* opens the cut-off. The shot drops from hopper *A* into bucket *B* and when

the straw breaks the bucket drops to platform *P*, forcing it down into the position of the dotted line *P'*. This pulls the wire *w* down, drawing the cut-off *n* into the position of the dotted line *n'*. The platform is held down by a spring at *c* while the shot is being weighed.

In order to show that there is a varietal difference in respect to strength of straw and that this difference can be measured by the machine described above, the breaking strengths of 100 culms each of Turkey and Red Wave wheats were taken. These breaking strengths are shown by the data presented in Table 1.

TABLE 1.—*Frequency Distributions for Variation in the Breaking Strength Determinations, Expressed in Grams.*

Class Values in Grams.	Number of Individuals in the Respective Classes. Turkey.	Red Wave.
0–150	13	
150–300	46	17
300–450	28	26
450–600	8	24
600–750	3	17
750–900	1	7
900–1050	1	2
1050–1200		2
1200–1350		4
1350–1500		1

Constants for the two varieties:

Turkey.	Red Wave.
$M = 298.5000 \pm 10.9432$	$M = 541.5000 \pm 18.2055$
$\sigma = 162.2415 \pm 7.7373$	$\sigma = 269.9115 \pm 12.8721$
$C = 54.3523 \pm 3.2694$	$C = 49.8452 \pm 2.9084$

Both varieties have a wide range of variation, the breaking strength of straw in the Turkey wheat varing from 82 to 902 grams, and that of the Red Wave varying from 163 to 1,400 grams. Both varieties, however, have about the same coefficient of variability, thus showing that the variability is about the same for each variety. The Red Wave has a mean breaking strength of 541.5000 ± 18.2055, while that of the Turkey is only 298.5000 ± 10.9432, which gives a difference in mean of 243.0000 ± 21.2415, a difference which is over eleven times its probable error. Although the number of individuals is not large, yet the data herein presented show that such differences may be measured with a fair degree of accuracy.

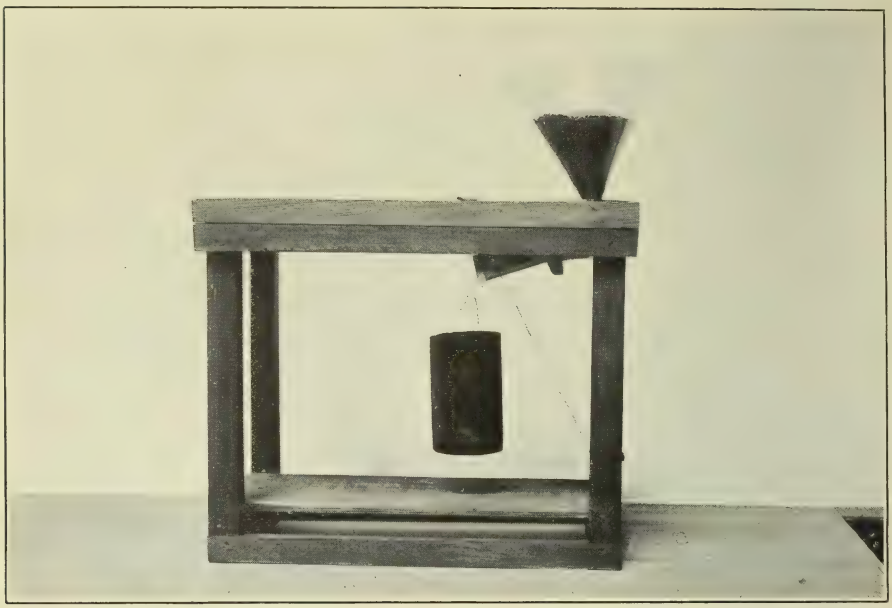

FIG. 1. Apparatus for Determining the Breaking Strength of Straw.

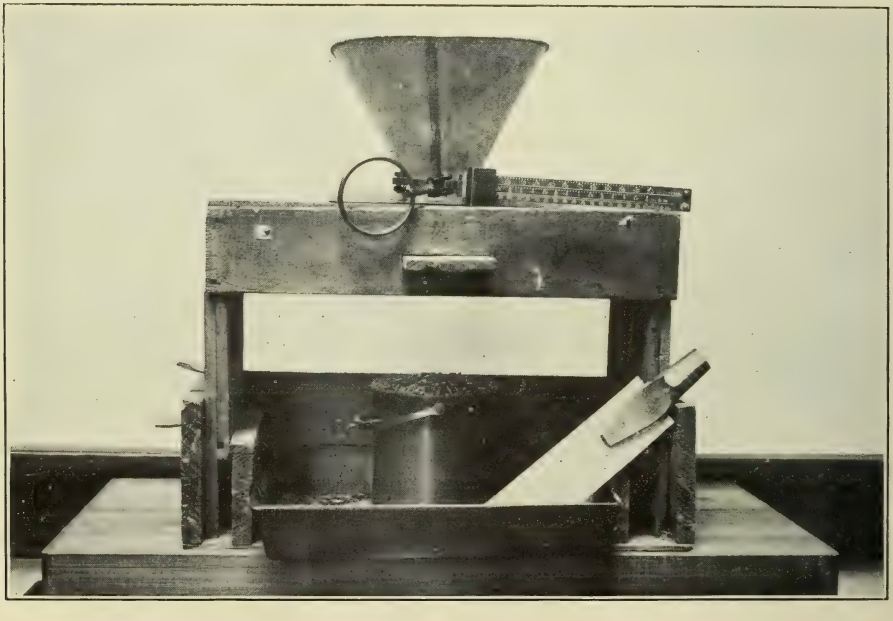

FIG. 2. Apparatus for Determining Weight per Bushel of Grains.

METHODS OF DETERMINING WEIGHT PER BUSHEL.[1]

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In a recent bulletin, Barber,[2] of the Maine station discussed methods for determining the weight per bushel of grains. The need for a uniform method for such determinations is pointed out in this bulletin, as is shown by the following statement made by the Federal Bureau of Standards in answer to an inquiry made by the Maine station:

"So far as the Bureau has any knowledge on the matter, there is very little care or uniformity of method used in filling the bucket with grain, although without doubt it is a matter to which greater attention should be given, as there is a decided difference in the amount of grain that may be contained in a measure according to whether it is struck off level as it falls into the bucket or is first shaken down. The most common practice of the matter is, probably, to merely dip the bucket into the grain to fill and then strike off the grain as it lies."

Four methods of determining weight per bushel were tested at the Maine station. The details of these methods are given briefly elsewhere in this paper. The method used in the department of plant breeding at Cornell University has given very satisfactory results, and as it differs in some essentials from those used by the Maine station, a comparison of the results obtained by the various methods seems desirable.

When investigations with cereals were begun by the department of plant breeding, it was deemed important to use a method for determining weight per bushel which would give accurate results and one in which all tests would be conducted in a uniform manner. It was also desired to use a method which would give results representing fairly the weights per bushel. It seemed that some method which would make it possible to fill the bucket in the same manner and with the same quantity each time would be satisfactory.

For this purpose Mr. H. W. Teeter of the department of plant breeding designed the apparatus shown in Plate I, Fig. 2. This

[1] Paper No. 52, Department of Plant Breeding, Cornell University, Ithaca, N. Y. Received for publication February 27, 1915.

[2] Barber, Clarence W., Note on the Accuracy of Bushel-Weight Determinations, Maine Agr. Exp. Sta. Bul. 226: 69–75, 1914.

apparatus consists of a stand with a funnel sufficiently large to hold more than enough oats to fill the 2-quart bucket, and with an opening 2 inches in diameter which is closed with a slide. The stand is so arranged that the distance between the bottom of the funnel and the top of the bucket is 6 inches. The stand may be adjusted so that when it is necessary to use a smaller tester the distance will be the same (6 inches) as when the larger tester is used.

With this apparatus, each variety tested may be handled in exactly the same manner, while different persons may determine the weights and obtain comparable results. The tests are not subject to the variations which may occur when one forces the grain into the bucket or dips the bucket into the grain. There is also an added advantage in that the results approximate the actual weight per bushel, which is not the case if the bucket is shaken or handled in any way that tends to pack the grain.

In order to make some comparisons between the Cornell method and those described in the Maine bulletin, a quantity of oats was thoroughly mixed and various tests were made, as described in the following paragraphs. As a sample was taken from the lot and tested it was put into another container, so that a different sample was used for each test. The descriptions of the methods used at the Maine station are quoted from the bulletin of that station previously mentioned, and the methods are numbered the same as in that bulletin. The grain tester was of the same kind as that used at the Maine station. The results of each test were read off from the percentage scale and were later changed to pounds. All determinations were made by Mr. Teeter, who has had considerable experience in obtaining such data.

The Cornell method consists of filling the large funnel with a certain quantity of grain each time. The slide closing the funnel is then opened and all the grain permitted to fall into the bucket. The measure is then struck in the ordinary manner, which is to draw a straight edge of some sort in a zigzag manner across the bucket. This was always done before the bucket was moved or shaken in the least.

The methods described in the Maine bulletin were as follows:

Method I. "The grain was poured into the bucket, filling the same rounding full and was not settled in any way." Then the top was leveled as in the Cornell method. From the statement in the Maine bulletin it is not clear whether the same quantity of oats was used each time or whether care was taken to pour always from about the same height. This was done in the tests cited in the present paper, with the exception of certain tests which will be referred to later.

Method II. "The bucket was filled rounding full by dipping it directly into the grain. The grain was not settled in any way." Then the top was leveled as in the Cornell method.

Method III. "The bucket was filled rounding full by dipping it into the grain and then shaken down once." After shaking the top was smoothed off as in the Cornell method.

Method IV. "The grain was poured into the bucket, filling it rounding full and settled by shaking down five times." After this the straight edge was used to level the surface as in the Cornell method.

The tests were made in the order given above. It was immediately apparent that the continuous handling was tending to break off the tips of the hulls, which would affect the results to a considerable extent. To determine this point definitely, after the 100 samples of each of the five lots had been run another set of 100 was made by the Cornell method. These are referred to in Table 1 as Cornell Method No. 2. The results for these determinations are given in Table 1.

TABLE 1.—*The Frequency Distribution of Determinations of the Weight per Bushel of Oats by Different Methods, with Variation Constants for Each.*

[First Set.]

Reading in Percentages.	Cornell Method, No 1.	Cornell Method, No. 2.	Maine Methods.			
			I.	II.	III.	IV.
46.0–46.4	1					
46.5–46.9	1					
47.0–47.4	35	12	32			
47.5–47.9	37	67	53			
48.0–48.4	24	20	13			
48.5–48.9	1	1	2	3		
49.0–49.4	1			10		
49.5–49.9				19		
50.0–50.4				41	1	2
50.5–50.9				16	3	
51.0–51.4				7	24	14
51.5–51.9				2	37	38
52.0–52.4				2	22	40
52.5–52.9					11	4
53.0–53.4					1	
53.5–53.9					1	1
54.0–54.4						1

VARIATION CONSTANTS.

Method.	Mean.	Standard Deviation.	Coefficient of Variability.
C. U. Method (1).....	30.5248±.0188	0.2780±.0133	0.9107±.0434
C. U. Method (2).....	30.5920±.0111	.1652±.0079	.5400±.0258
Maine Method I.....	30.5120±.0141	.2084±.0099	.6830±.0326
Maine Method II.....	32.1472±.0283	.4191±.0200	1.3037±.0622
Maine Method III.....	33.1776±.0241	.3570±.0170	1.0760±.0513
Maine Method IV.....	33.2384±.0223	.3310±.0158	.9958±.0475

It is seen that the means for the Cornell method (1) and Maine method (1) are practically the same. The standard deviations, however, are considerably different, the difference amounting to .0696 ± .0166. How much of this may be due to the fact that the oats had been handled once is impossible to determine exactly. There is evidently less variation when Method I is used in this case. However, when one considers the statement under Method I that the same quantity of oats was used for each test and that they were always poured from nearly the same height it is clear that there is really little difference between Method I and the Cornell method.

The difference between the means of Methods I and II amounts to 1.6352 ± .0316. The standard deviation of Method II is greater. This is in accordance with the results recorded in the Maine publication. The coefficient of variability, however, is greater for Method II by .6207 ± .0702, which shows that the relative variability is greater when this method is used.

The mean increases when Method III is used in comparison with Method II, as is shown by the difference, 1.0304 ± .0372. The differences between the standard deviation and coefficient of variability of Methods II and III are .0621 ± .0262 and .2277 ± .0806 respectively. This indicates that the variability becomes less as the method of filling is changed so that the oats are packed to some extent.

When Method IV is used the mean is about the same as when Method III is used. The standard deviation, however, is slightly less, as well as the coefficient of variability. This indicates that the settling of the grain tends to lessen the variability to some extent. That part of this effect may be caused by the fact that the grain had been handled so much is shown by the second test run by the Cornell method. This shows the mean to be about the same, although slightly increased, while the standard deviation and coefficient of variability are considerably less than is shown by the Cornell method (1). The differences between the standard deviation and coefficient of variability are .1128 ± .0155 and .3707 ± .0505 respectively. This indicates clearly that the handling of the oats makes it possible to obtain a more uniform sample than can be done at first.

Since this seemed so important, it was decided to obtain a new lot of the same variety of oats and make the determinations in such a way that all the samples obtained would be more nearly uniform so far as the oats were concerned. This was done as follows: Five determinations were made by the Cornell method, then 5 with Method I, 5 with Method II, and so on until 5 samples had been run by each

method. The operation was then repeated until 100 determinations had been made by each method. The results are given in Table 2.

TABLE 2.—*The Frequency Distribution of Determinations of the Weight per Bushel of Oats by Different Methods, with Variation Constants for Each.*
[Second Set.]

Readings in Percentages.	Cornell Method.	Maine Methods.			
		I.	II.	III.	IV.
46.5–46.9	2	4			
47.0–47.4	44	49			
47.5–47.9	43	36			
48.0–48.4	10	11			
48.5–48.9	1		1		
49.0–49.4			4		
49.5–49.9			18		
50.0–50.4			48		
50.5–50.9			15	1	
51.0–51.4			9	9	
51.5–51.9			5	15	1
52.0–52.4				29	9
52.5–52.9				17	15
53.0–53.4				17	16
53.5–53.9				11	8
54.0–54.4				1	18
54.5–54.9					18
55.0–55.4					10
55.5–55.9					5

VARIATION CONSTANTS.

Method.	Mean.	Standard Deviation.	Coefficient of Variability.
C. U. Method.....	30.4448±.0144	0.2140±.0102	0.7029±.0335
Maine Method I.....	30.4128±.0147	.2182±.0104	.7175±.0342
Maine Method II.....	32.2304±.0245	.3632±.0173	1.1269±.0537
Maine Method III.....	33.6064±.0323	.4796±.0229	1.4271±.0681
Maine Method IV.....	34.4704±.0453	.6711±.0320	1.9469±.0928

These results do not agree altogether with those given in Table 1. The mean shows an increase with those methods in which the oats are settled.

The means, standard deviations, and coefficients of variability for the Cornell Method and Method I agree very closely, indicating that it makes little difference which method is used. In fact, as has been pointed out above, there is really no great difference between the two methods as performed in our laboratory. It is difficult always to pour from the same height, to use the same quantity of oats, etc., therefore it is better to use the apparatus which has been described under the Cornell method and which any one may duplicate. It is easier to give directions which can be followed with this apparatus than with

Method I, or in fact with any method where the individuality of the experimenter plays an important part.

The difference in mean between Method II and Method I is $1.8176 \pm .0286$, which shows beyond doubt that the weight per bushel is increased with this method. The standard deviation is greater when Method II is used by $.1450 \pm .0202$, which, considered with the difference in the coefficient of variability, $.4094 \pm .0637$, indicates that the variability is slightly greater in Method II. When Method III is used the mean is greater than that of Method II by $1.3760 \pm .0405$. The standard deviation is only slightly greater, the difference being $.1164 \pm .0287$, and the coefficient of variability is likewise greater by $.3002 \pm .0867$. The two constants indicate slightly the tendency to increased variability, although the differences are not significant when the probable error of the difference is considered.

Method IV[3] gives a mean slightly higher than Method III. The standard deviation and coefficient of variability also indicate that the variability is somewhat greater, although the differences between the standard deviation and coefficient of variability are not great. When Method IV is compared with Method I and the Cornell method, a marked difference is shown in the mean, standard deviation, and coefficient of variability. The differences in mean between Method IV and Method I and between Method IV and the Cornell method are $4.0576 \pm .0476$ and $4.0256 \pm .0475$ respectively. The differences are practically the same, showing again the similarity of Method I and the Cornell method. The same may be said of the differences in the standard deviation and coefficient of variability. The differences between the standard deviation in the same order are $.4529 \pm .0336$ and $.4571 \pm .0336$, while those between the coefficient of variability are $1.2294 \pm .0989$ and $1.2440 \pm .0987$.

This clearly indicates for these data that the mean weight per bushel is abnormally high and that the variability is not lessened by the methods which tend to settle the oats.

These results are in exact contradiction to those obtained at the Maine station. It is believed, as has been pointed out, that as the oats are handled more and more the variability of the weights obtained becomes less, and that by the method used at Maine the tendency would be for the last lot of samples taken to become less variable. This is clearly shown by the results obtained by the Cornell

[3] In this lot under Method IV the tester was filled again after shaking and before striking. This was also done in the next lot but not in the first lot in Table 1.

method (1 and 2), given in Table 1. Another reason for the differences between the Maine results and the ones obtained at Cornell is that different persons conducted the tests. It is not possible for two persons to shake a measure several times and settle it in exactly the same way. It is clear, then, that one person may settle the oats more than another and such results could not be used in comparison with those obtained elsewhere.

Since it has been shown that there was little difference between Method I and the Cornell method as the determinations were made in our laboratory, it seemed well to make a new set of determinations in which Method I as described would be interpreted generally. That is, nothing is said in the description of the method as used at Maine regarding the manner of pouring, nor is it stated whether the same quantity of oats was used each time, whether the pouring was done all at once or whether small quantities of oats were obtained so that the oats might have a chance to settle.

TABLE 3.—*The Frequency Distribution of Determinations of the Weight per Bushel of Oats by Different Methods, with Variation Constants for Each.*

[Third Set.]

Readings in Percentages.	Cornell Method.	Maine Method.	
		I.	IV.
47.0–47.4	14	2	
47.5–47.9	32	2	
48.0–48.4	44	12	
48.5–48.9	10	19	
49.0–49.4		25	
49.5–49.9		21	
50.0–50.4		15	
50.5–50.9		4	
51.0–51.4			
51.5–51.9			
52.0–52.4			1
52.5–52.9			1
53.0–53.4			16
53.5–53.9			22
54.0–54.4			21
54.5–54.9			28
55.0–55.4			10
55.5–55.9			1

VARIATION CONSTANTS.

Method.	Mean.	Frequency Distribution.	Coefficient of Variability.
C. U. Method.....	30.7200±.0174	0.2573±.0123	0.8376±.0399
Maine Method I.....	31.5392±.0324	.4803±.0229	1.5229±.0726
Maine Method IV.....	34.6880±.0288	.4277±.0204	1.2330±.0588

Consequently, a third set of determinations was made in which the Cornell method was compared with Method I, when the pouring was done as any person might do or as has been suggested in the preceding paragraph. A lot was also run by Method IV the same as in the second set (Table 2). The results of these determinations are given in Table 3. It is clear from the frequency distributions that there is greater range in Method I than was observed in Table 1.

The mean is greater when the results have been obtained by Method I as indicated than when obtained by the Cornell method, the difference being $.8192 \pm .0368$. This shows that when each determination is not made in exactly the same way there is a tendency for the oats to settle, especially when enough is not poured in at once to fill the bucket rounding full.

The standard deviation shows a difference of $.2230 \pm .0260$ and the coefficient of variability shows a difference of $.6853 \pm .0828$. These constants indicate also that there is greater variability than with the Cornell method.

Again, Method IV shows a greater mean than either of the other methods. Greater variability is also obtained than when the Cornell method is used.

Taken as a whole, these results show the need of a uniform system for the determination of the weight per bushel of grain. It is evident that it is difficult to follow any method that permits of differences due to the manipulator. The method suggested here may not be the best, yet it is possible for any person to duplicate it exactly. This renders it possible to make all weight per bushel results comparable. This point is very important, since with the methods now in use at different places the weight per bushel may vary several pounds, depending entirely upon the manner of making the test.

Members of the American Society of Agronomy who are interested in apparatus for the accurate determination of bushel weights will be glad to know that the office of grain standardization, U. S. Department of Agriculture, is developing an apparatus for commercial use which it is hoped will be ready to place on the market in a short time. The device does not differ greatly from that here described by Doctor Love, though it does vary in some particulars. When it is ready for the public, further notice concerning it will be published in the JOURNAL.—Editor.

POT TESTS WITH FERTILIZERS COMPARED WITH FIELD TRIALS.[1]

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INTRODUCTION.

After the reconnaissance soil survey of Ohio had determined the important soil types of the State, it was purposed to make studies upon these different types to find out their peculiar requirements. Among the most important of these studies is the determination of the relative need of the different types for the three principal fertilizing elements.

While field trials are considered the most reliable method of solving this question, they are expensive and must be "systematically planned and thoroughly executed over a period of years, long enough to give a fair average of climatic conditions, which would mean at least ten or twelve years," before the experimenter "can feel that he has the solid ground of positive knowledge under his feet."[2] A quicker and less expensive method is therefore very desirable. Several such methods have been proposed, among which may be mentioned chemical analysis, wire basket tests and pot tests.

The results with pots seemed to give most promise and it was therefore decided to make pot tests with soils as similar as possible to those upon which field trials are being conducted, and to compare the results with those secured in the field. In this work the idea has been to duplicate field conditions and treatments as nearly as possible.

Ohio has several experiment farms located in various parts of the State on widely different types of soils. Upon these, fertilizer plot work has been conducted for periods ranging from ten to twenty years. Soils from the farms at Wooster, Strongsville and Carpenter have been studied in pot tests and the results so far secured are reported here.

[1] Received for publication April 21, 1915.

[2] Thorne, Chas. E., How to Determine the Fertilizer Requirements of Ohio Soils, Ohio Agr. Expt. Sta. Cir. 79, p. 3, 1908.

Pots.

The pots used were 5-gallon glazed clay butter-crocks, about 10½ inches in diameter and 12 inches deep. A small hole, over which a piece of broken crockery was placed before filling, was punched in the bottom to provide drainage. It was found necessary to have all pots as nearly uniform in depth and diameter as possible.

Collecting Samples and Potting.

As it was impossible to obtain soil from the unfertilized field plots, samples were taken from unfertilized land, located as nearly as possible to the field pots with which the pot results were to be compared. One objection to the use of this soil is that the unfertilized strips, except at Strongsville, have not been cultivated for years, while the plots have been. This difference in treatment has undoubtedly affected their fertility, especially the nitrogen content.

The surface soil and the first 6 inches of the subsoil were collected from several places in the same field and taken to the greenhouse as soon as possible, where each was mixed separately by shoveling over on a cement floor. Equal weights (about 10 kg.) of both soil and subsoil were used in each pot. In potting, a sufficient quantity of the subsoil to cover the bottom to a depth of an inch or so was placed in the pot. The balance of the earth and enough water to saturate it thoroughly were then poured in simultaneously, the same quantity of water being used in each pot. The pots were then allowed to settle for several days. The surface soil was then added to the pots and settled like the subsoil, with enough water to saturate it thoroughly. The pots were then left until the soil was in good working condition, usually for two or three weeks, when they were cultivated, fertilized, and planted. Although it may not be possible to settle the soil absolutely by this method, pots which have been cropped in the greenhouse for two years have not settled appreciably since first planted and it is believed that the method used gives the easiest and nearest approach to field conditions. As duplicate tests showed little difference from the use of distilled or tap water, the latter is now used.

Treatment.

Every treatment was tested in triplicate, applying each fertilizer at the same rate as in the field. Commercial fertilizers were used in all cases. However, when lime was required, c.p. calcium carbonate was applied some time before fertilizing, by sprinkling the desired quantity through a small 20-mesh screen and working it into

the first few inches of the surface soil with a spatula. The fertilizers were applied by removing about 1 inch of the surface soil and mixing the fertilizer with it by rolling on glazed paper. This soil was then spread evenly over the surface of the pot and harrowed in.

Wheat Used as Indicator.

As wheat has shown a very marked difference in its response to the different fertilizer treatments in the fields and as it grows well under greenhouse conditions, this crop was selected for the experiment. It was sown in three parallel rows, about 30 to 35 seeds being used in each pot. After the plants were well started they were thinned to 25 per pot, care being taken to leave uniform plants.

Shall the Crop be Matured?

When this work was begun, it was planned to grow the crop to maturity, but insects and fungi attacked the first plants so severely that it was necessary to harvest the crop when the plants were about one month old. However, the various treatments already showed such differences that it was decided to air-dry and weigh the plants from each pot. The relative fertilizer requirements of this soil, as indicated by these results, corresponded so nearly with the field trials that another test was made on the same soil, but without growing the crop to maturity. Again the indications were very similar to those shown by the field trials, and no attempt has since been made to mature the crop, it being harvested when about one month old.

That the use of this short period of growth is permissible is substantiated by field observations. It has frequently been noted at the Ohio stations that those plots which produce the largest yields indicate this by a larger growth when the crop is still young. Dr. Wheeler states that "The more common experience of close observers is to the effect that if slight soil deficiencies or faults exist, the plants are likely to show them even while they are very young and that the relative differences remain much the same until maturity."[3] Many similar citations could be given. The results of these tests and the field trials, as can be seen from the data which follow, agreed in regard to the element most needed by all three soils and also gave a very good indication of the relative effects of the other two elements. Since the object of this work was to test the value of the pot method as a rapid means of determining the fertilizer require-

[3] Wheeler, H. J., Brown, B. E., and Hogenson, J. C., A Comparison of Results Obtained by the Method of Cultures in Paraffined Wire Pots with Field Results on the Same Soil, R. I. Agr. Expt. Sta. Bul. No. 109, p. 16.

TABLE 1.—*Yields and Increases in Grams of Dry Matter Obtained with Wheat in a Fertilizer Test in Pots.*

Fertilizer Applied.	Wooster Soil.					Strongsville Soil.		Carpenter Soil.	
	First Test.		Second Test.		Ave. Inc. in Both Tests.				
	Dry Weight.	Ave. Inc.	Dry Weight.	Ave. Inc.		Dry Weight.	Ave. Inc.	Dry Weight.	Ave. Inc.
None	2.34 2.12 1.88 ±.15	——	2.07[1] 1.77 1.72 ±.10	——	——	3.63 3.62 3.62 ±.004	——	4.3 4.2 4.1 ±.06	——
P	4.74[1] 2.59 2.25 ±.90	.31±.11	2.66 2.27 2.12 ±.19	.61±.11	.46±.10	7.85 7.68 6.60[1] ±.45	4.13±.05	7.0 6.9 5.1[4] ±.71	62.±.03
K	3.06[1] 2.14 2.02 ±.38	−.03±.04	2.25 2.18 1.93[1] ±.11	.47±.16	.22±.16	4.83 4.52 3.98 ±.27	.82±.17	4.9 4.8 4.1[4] ±.29	.6±.03
N	2.26 2.03 1.67[1] ±.20	.03±.07	2.05 2.03 1.91 ±.07	.26±.03	.14±.07	4.69[1] 4.42 4.31 ±.13	.74±.03	4.4 4.4 3.8 ±.23	.2±.00
NP	3.54 3.36 2.35[1] ±.43	1.34±.06	3.03 2.81 2.66 ±.12	1.09±.07	1.21±.08	9.04 8.74 8.22 ±.27	5.04±.16	7.0 6.7 6.3 ±.24	2.5±.16
PK	3.73 3.72 3.55[1] ±.06	1.61±.00	3.54 3.48 2.91[1] .23	1.77±.02	1.69±.05	8.14 7.90 7.72 ±.14	4.30±.08	6.6 6.0 5.8 ±.39	1.9±.18
NK	2.38 2.26 2.17 ±.07	.16±.05	2.27 2.23 2.15 ±.04	.48±.02	.32±.11	4.21 4.00 3.82 ±.13	.39±.07	5.2 4.7 4.5 ±.34	.6±.18
NPK	3.99 3.37 2.62 ±.40	1.22±.36	3.99[1] 3.69 3.59 ±.14	1.90±.03	1.55±.23	7.94 7.18 5.34[1] ±.89	3.94±.25	7.5 7.1 6.8 ±.33	2.9±.18

[1] Not included in average because they differ from the other two members of the set by an amount greater than the probable error.

ments of soils, it therefore hardly seems advisable to take the additional time and trouble to grow the crop to maturity, at least in the case of wheat. However, it is purposed to investigate this question further in order to determine definitely this point. It is believed that a direct comparison of pot to field results furnishes the most rigid and reliable test of the value of this or any other method.

Results of Pot and Field Studies.

Two tests, using different lots of soil, have been made on the Wooster soil, and one each on the Strongsville and Carpenter soils. In every test the same kind and quantity of fertilizer per acre was used in the pots as was applied on the wheat crop in the field.

At Wooster and Strongsville, which have received similar treatment, all three elements are used alone, in combinations of two, and all three together. These include plots 2, 3, 5, 6, 8, 9, and 11 of the 5-year rotation. The quantities of fertilizers per acre used on wheat, either alone or in combination, were 160 pounds of acid phosphate, 100 pounds of potash, 120 pounds of nitrate of soda, and 50 pounds of dried blood. In addition, 2,000 pounds of lime or 4,000 pounds of ground limestone per acre were added.

On the plots at Carpenter, nitrogen and potash are not used alone, but they were in the pots. The quantity of fertilizer applied is also different from that used at Wooster and Strongsville, being 120 pounds of acid phosphate, 20 pounds of muriate of potash, 60 pounds of nitrate of soda, and 30 pounds of dried blood. Here 2,000 pounds of lime was added.

Table 1 presents the actual yield of each pot and the average increase or decrease resulting from each treatment, as compared with

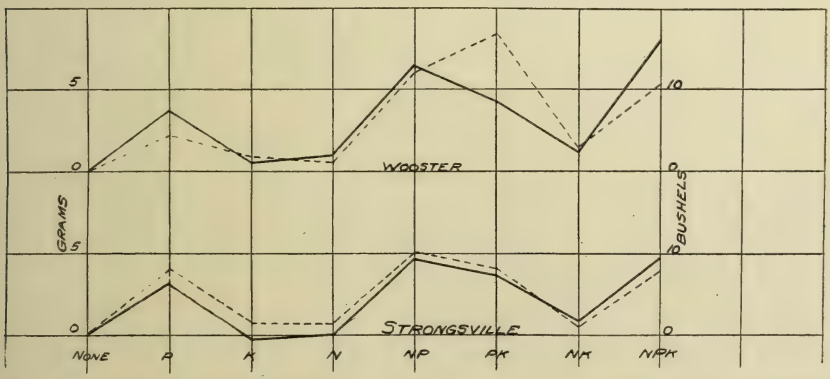

Fig. 5. Relation between yields of plots and pots. The solid lines represent the yields of plots and the broken lines the yields of pots.

the average of the untreated pots. The probable errors given have been calculated according to the method of least squares.

The average increase or decrease produced by each treatment in the pots and that resulting from the same treatment on the plots is shown in Table 2. A comparison of these data is shown graphically in figure 5. No curves have been made of the Carpenter results, since nitrogen and potassium were not applied alone on the plots.

TABLE 2.—*Increases Obtained from Fertilizers on Plots and in Pots.*

Fertilizer Applied.	Field Test.[1]		Pot Test, Grams.
	Grain, Bushels.	Straw, Pounds.	
	Wooster Soil		
P	7.58±.7	734± 59	.46±.10
K	1.01±.2	149± 34	.22±.16
N	1.87±.2	321± 43	.14±.07
NP	13.17±.9	1,376± 90	1.21±.08
PK	8.76±.6	800± 77	1.69±.05
NK	2.67±.2	345± 40	.32±.11
NPK	15.93±.9	1,806±100	1.55±.23
	Strongsville Soil		
P	6.58±.50	603± 64	4.13±.05
K	−.33±.20	−69± 11	.82±.17
N	.00±.22	7± 24	.74±.03
NP	9.54±.56	876± 23	5.04±.16
PK	7.47±.40	577± 41	4.30±.08
NK	1.50±.34	184± 43	.39±.07
NPK	9.25±.59	947± 73	3.94±.25
	Carpenter Soil		
P	4.64±.3	485± 50	2.7 ±.03
K	No plot	No plot	.6 ±.03
N	No plot	No plot	.2 ±.00
NP	6.10±.7	708± 74	2.5 ±.16
PK	6.52±.4	668± 52	1.9 ±.18
NK	2.07±.4	200± 34	.6 ±.18
NPK	9.11±.6	983± 99	2.9 ±.18

[1] Wooster soil, 20-year average; Strongsville soil, 18-year average; Carpenter soil, 9-year average.

While the effects of the different treatments in the pots do not always correspond exactly to those in the field, there is a striking similarity in the trend of the curves. The most apparent variation is in the effect of PK on the Wooster soil.

In the interpretation of the results of fertilizer studies it should be kept clearly in mind that the fundamental object is to determine the need of a soil for the different elements. While Table 2 and the curves which accompany it show the relation of one treatment to

another, they do not develop in detail the effect which an element has when used in combination with the other elements. This may be shown by a method of differences, which though evidently empirical is of great value in estimating the true effect of an element. Table 3 has been formed in this way from the data in Table 2. It shows the effect of the elements when used alone and in combination, both on the plots and in the pots.

TABLE 3.—*Increases of Wheat from Elements (N, P and K) Alone and in Combination on Plots and in Pots.*

	Wooster.		Strongsville.		Carpenter.	
	Plots.	Pots.	Plots.	Pots.	Plots.	Pots.
	Bushels.	*Grams.*	*Bushels.*	*Grams.*	*Bushels.*	*Grams.*
Nitrogen:						
N alone	1.87	0.14	0	0.74		0.2
NP–P	5.59	.75	2.96	.91	1.46	−.2
NK–K	1.66	.10	1.83	−.43		.0
NPK–PK	7.17	−.14	1.78	−.36	2.59	1.0
Average	4.07	.21	1.64	.21		.25
Phosphorus:						
P alone	7.58	.46	6.58	4.13	4.64	2.7
NP–N	11.30	1.07	9.54	4.30		2.3
PK–K	7.75	1.47	7.80	3.48		1.3
NPK–NK	13.26	1.23	7.75	3.55	7.04	2.3
Average	9.97	1.06	7.92	3.86		2.15
Potassium:						
K alone	1.01	.22	−.33	.82		.6
NK–N	.80	.18	1.50	−.35		.4
PK–P	1.18	1.23	.89	.17	1.88	−.8
NPK–NP	2.76	.34	.49	−1.10	3.01	.4
Average	1.44	.47	.64	−.11		.15

From Table 3 it is apparent that, no matter how the effect of the elements is measured, on all the soils studied phosphorus has always given the largest increase and is consequently the element most needed. In this important fact the pots and plots agree.

In regard to the relative need of potash and nitrogen at Wooster the plots and pots do not agree. The latter indicate a lower requirement for nitrogen than for potassium, while the opposite is true in the field. This apparent contradiction is believed to be due to the fact that the soil used in the pots at Wooster was taken from under sod and therefore probably contained more nitrogen than the long cultivated plots. In this connection it might be noted that out of the 20 crops of wheat at Wooster potash has produced a greater increase than nitrogen in seven different seasons, or the chances are practically 2 to 1 in favor of nitrogen.

The Strongsville results show a close agreement, the average effect

of each element as determined in Table 3 indicating the same as the field trials. They also show that phosphorus, as compared to nitrogen and potassium, has given a greater increase than at Wooster. This is also indicated in the fact that the 18-year average at Strongsville shows no effect from nitrogen and a decrease of only 0.33 bushel from potassium, which emphasizes the small need of this soil for either of these elements.

It must be remembered that the wheat on the plots is in a 5-year rotation and is preceded by corn and oats, each of which is fertilized. In the pots wheat is the only crop grown, therefore any residual effect due to the fertilization of previous crops is not present. When this and other factors previously mentioned are considered, the agreement between the field and pot results as to the relative need of the soil for the different elements is remarkably close. In fact, it is closer than that between different sections in the field, as may be seen by comparing the data in Table 4 with that in the previous tables. As wheat on the plots is grown in a 5-year rotation, at the end of 20 years it has appeared four times on each section. The figures given in Table 4 represent the average yields and increases of these four crops on each section at Wooster.

TABLE 4.—*Average Yields and Increases*[1] *of Wheat in 5-Year Rotation at Wooster by Sections for 20-Year Period.*

	Average Yields in Bushels, 4 Crops					Average Increases in Bushels, 4 Crops.				
Treatment.	*A*	*B*	*C*	*D*	*E*	*A*	*B*	*C*	*D*	*E*
Check	10.97	20.89	4.34	8.26	10.37					
P	18.67	24.09	13.09	17.65	19.25	6.11	4.24	8.94	9.65	8.94
K	17.72	18.66	3.96	7.88	11.71	3.57	— .14	.005	.12	1.49
Check	15.74	17.76	3.76	7.51	10.16					
N	16.92	20.92	5.44	8.35	12.52	1.72	2.96	1.71	.66	2.33
NP	23.39	32.35	17.16	21.83	25.74	8.72	14.17	14.70	13.96	15.51
Check	14.13	18.38	3.67	8.04	10.26					
PK	21.27	24.19	13.73	19.52	42.59	7.50	5.15	9.90	11.30	10.04
NK	17.04	23.24	4.96	11.05	12.00	3.63	3.54	.79	2.65	2.74
Check	13.04	20.35	4.42	8.57	8.56					
NPK	25.59	38.21	18.50	25.25	26.86	12.06	18.28	14.46	16.57	18.27

[1] The method of calculating increases is explained by Dr. Chas. E. Thorne, as follows: "In all these experiments with fertilizers and manure every third plat is left untreated, as a check plat, and the increase for each treated plat is found by comparing its yield with that of the untreated plats between which it lies. In calculating increase it is assumed that if the yield of Plat 1, for example, were 30 bushels, and Plat 4, 33 bushels, that of Plat 2, had it not been manured, would have been 31 bushels, and that of Plat 3, 32 bushels." Ohio Agr. Expt. Sta. Bul. 184, p. 229, 1907.

An examination of these data will show that the yields and increases from the same treatment vary greatly on the different sections, due primarily to soil and seasonal differences. While it is seen that all sections, like the pot tests, show a greater response to phosphorus than to nitrogen or potassium, there is a considerable variation in the response to either of the last two elements or the various combinations in which they appear. Section D, which has given the greatest increase from P, has given the least increase from N and very little from K; Section B, which has given the least response to P, has given the greatest response to N and has shown a decrease from K; while Section A, which shows the smallest increase from NP of all the sections, shows the largest increase from NK. Although these variations between the different sections occur, the indications, as to their relative need for the different elements, are the same, with the exception of Section A, where the plot receiving potassium alone has given an abnormal yield, which Director Thorne states is probably due to some previous treatment of the land.

Pot Work at Other Stations.

In connection with this work a circular letter was sent to every experiment station in the United States, requesting information concerning their experience with fertilizer pot work. As several suggested that a report of this information be published, it is summarized herewith.

Replies were received from 41 stations, of which only 14 reported pot work with fertilizers, while 3 stated that they used outdoor cylinders. Many of the western stations state that as yet soil fertility is not a prominent question.

The size of the pots used varied from 1 to 6 gallons, with the majority preferring a 4-gallon to 6-gallon pot.

Surface soil only is used by 7 stations; both surface and subsoils by 4; while 3 report that as a rule they use only the surface, but occasionally both. Those that reported cylinders use both surface and subsoil.

Some of the replies stated that duplicate pots were used, and a few reported using triplicates. While every report did not cover this point, it is assumed that all carry on their tests in duplicate at least.

In regard to mixing and potting the soil, the stations which reported successful pot studies do not dry or excessively handle the soil by pounding, fine screening, etc.

A few stations reported trouble with pots drying out. It is to be noted that these used surface soil only.

Commercial fertilizers were used except in a few cases where c. p. salts were necessary.

Every station reports that a slight excess of seed is sown and that the plants are thinned to the same number per pot. All based their conclusions on the dry weight, while a few record the green weight also.

While a few state that they have compared their results with field trials, apparently none have compared their data with long-time field experiments. It is evident that the object of many of the studies has been to question the availability of certain fertilizers rather than to determine the relative need of the soil for the principal plant foods.

Among the stations which report success with fertilizer pot studies, it is the consensus of opinion that if one element is needed the pot test is quite reliable in indicating it, while if two or more elements are lacking the pots may differ from field indications.

Conclusions.

From the data presented in this paper and from the experience at other stations, it would appear that the best results may be expected if the following suggestions are adhered to rather closely in carrying on pot work:

The soil should be gotten into the pots in as nearly the same relative position and condition as in the field. Both soil and subsoil should be used, the surface soil being taken to the depth at which the most marked change takes place, usually about the depth to which it is plowed.

Air-drying and excessive handling should be avoided. The soil should be settled to as nearly field condition as possible. Water has been used very satisfactorily for this purpose in the work reported in this paper.

The same fertilizer applied in practice has generally been used and is mixed with the first 3 or 4 inches of soil. It is believed best to simulate field practice as nearly as possible.

A somewhat larger quantity of seed per acre should be sown and the plants thinned to about the same number per acre as in the field and to an equal number per pot.

While most stations have grown the plants to maturity, the results secured here seem to show that with wheat a period of one month to six weeks is sufficient to indicate the relative fertilizer need of the soils studied.

The dry weight is considered most reliable.

The tests should be made in not less than triplicates and statistical methods should be applied.

These fertilizer pot tests have been interpreted from the standpoint of the relative need of the soil for the different elements. As a comparison of the results of the pot tests and field trials made in this way agree very closely, it seems that pot tests may be of very great value in helping to solve this very important question. By their use it should be possible to obtain data which would enable one to determine with considerable accuracy about what treatment most probably will give best results, and this treatment can then be tried along with others in the regular field trials. It will then be possible to see whether the indications secured in the pots apply in actual field trials, as has been true in the case of the soils reported upon in this paper.

VARIATIONS IN SOY BEAN INOCULATION.[1]

JOHN H. VOORHEES.

During the summer of 1913 a number of cooperative tests were conducted to determine the growing period of several varieties of soy beans in different parts of New Jersey. Observations made on the inoculation of different varieties on the farm of Dr. D. H. McAlpin, Morris Plains, N. J., brought out some interesting points that seem worthy of special mention.

The test at this place was conducted on a well-drained, medium-heavy clay loam soil. Oats and field peas had been grown the previous year upon a well-manured and fertilized corn stubble. This crop was harvested for hay and a cover crop of rye and hairy vetch planted. The cover crop was plowed under during the early part of May and the soy beans planted during the first week in June. One-acre plats were sown to each of the following varieties: Mikado, Peking, Haberlandt, Tarheel Black (Black Shanghai, S. P. I. No. 14952), Brown (Trenton, S. P. I. No. 24610), and Auburn. Each field was divided lengthwise into two parts, "nitrogerm" being used on one and "farmogerm" on the other. Two rows in the center of each plat received no treatment, thus separating the two kinds of inoculation. All varieties germinated well and made splendid growth.

In observations made June 25 the plants of all varieties bore root nodules except the Haberlandt, which seemed to lack them entirely.

[1] Received for publication December 5, 1914.

On September 8 the nodules on the Mikado were very numerous, spreading around the tap root in a close mass, this also being true to a less extent with the Auburn and Brown varieties. The Tarheel Black had a few large nodules scattered on the finer roots as far as 8 to 12 inches from the tap root. The Peking had a moderate number of medium-sized nodules located from 3 to 4 inches from the tap root. No nodules, however, were found on the Haberlandt. In two rows where the Brown and Haberlandt varieties were mixed in planting, the root systems became rather closely associated. After separating the roots of the two varieties, it was found that the Brown variety had numerous nodules scattered throughout, but no nodules were found on the roots of the Haberlandt. In all over one hundred plants were examined and the same conditions found in each case. It is quite evident that nodule bacteria capable of inoculating the Brown variety were present in the plat, but that the same bacteria did not cause nodules to form on the Haberlandt.

In ascribing a reason for the lack of inoculation on the Haberlandt, it is the writer's opinion that different varieties of the same legume bear different and definite powers of resistance to association with symbiotic bacteria. An alternative suggestion by Dr. Mel. T. Cook of this station, is that the association of nodule bacteria with legumes really causes a disease, the harmful effects of which are overcome by the benefit obtained through the addition of nitrogen to the food supply of the plant.

It was the writer's desire to continue the experiment in 1914, reversing the direction of the rows, but unfortunately he was unable to continue the work. The results obtained are given with the hope that they may be used by some other worker. New Jersey Experiment Station, New Brunswick, N. J.

Some similar results concerning variation in soy bean inoculation were noted at the West Tennessee Experiment Station at Jackson, in the season of 1911. In 1910 Mr. S. A. Robert, superintendent of the station, observed that the Acme and Tokio varieties of soy beans lacked root nodules, while the Mammoth, planted under the same conditions, produced many of them. The next season, 1911, the Mammoth, Acme, and Tokio were planted in a field where the Mammoth had been grown in 1910 and where it was well supplied with nodules. In the latter part of September the writer had occasion to examine a large number of plants of these three varieties and in no case were nodules found on plants of the Acme and Tokio varieties, while the plants of the Mammoth had numerous nodules. In the varietal tests conducted at Arlington Experimental Farm, Virginia, for a number of seasons, the Haberlandt was as well supplied with nodules as most of the other varieties.—W. J. Morse, U. S. Department of Agriculture.

AGRONOMIC AFFAIRS.

MEETINGS OF THE SOCIETY.

The attention of members of the American Society of Agronomy is again called to the two meetings of the society which are to be held within the next few months. The first, a joint meeting with the Great Plains Coöperative Association, will be held at Mandan, N. Dak., on July 14–16. The second, the annual meeting of the society, will be held at Berkeley, Cal., August 9 and 10. At the same time, the American Farm-Management Association and the Society for the Promotion of Agricultural Science will hold their sessions. On August 11–13 the Association of American Agricultural Colleges and Experiment Stations will meet at Berkeley. Members who expect to present papers at either the Mandan or the Berkeley meeting are urged to send the titles to the secretary of the society, so that the programs can be prepared well in advance of the meetings. Papers for the Mandan meeting should have a bearing on some agronomic problem in the Great Plains area.

MEMBERSHIP CHANGES.

The total membership reported in the previous number of the JOURNAL was 438. Since that time, 26 new members have been received and 3 members have resigned. On March 31, according to the constitution of the Society, those whose dues for 1914 were still unpaid automatically lapsed. Twenty-four such lapsed members are reported herewith. This is the largest number of lapsed members yet reported; on the other hand, the accession of new members has been more rapid in 1915 than ever before. The total for the year so far, 71, just equals the largest number of new members previously added to the Society in any one entire year. The total number of new members for 1915 should not be less than 100. The net membership of the Society at this date is 437. The names and addresses of new members, the names of those who have resigned or lapsed, and the changes of address are as follows:

NEW MEMBERS.

BANCROFT, Ross L., Iowa State College, Ames, Iowa.
BENTON, T. H., Iowa State College, Ames, Iowa.

Bolland, Jens, Box 242, South Dakota State College, Brookings, S. Dak.
Carnes, Homer M., 728 14th St., Corvallis, Ore.
Cook, I. S., Jr., College of Agriculture, Morgantown, W. Va.
Dean, H. K., Umatilla Experiment Farm, Hermiston, Ore.
Dorsey, Henry, College of Agriculture, Morgantown, W. Va.
Forman, L. W., Iowa State College, Ames, Iowa.
Hanson, H. P., Old Agrl. Hall, Iowa State College, Ames, Iowa.
Jensen, L. N., Cereal Field Station, Amarillo, Texas.
Kemp, W. B., College of Agriculture, Morgantown, W. Va.
Kinney, H. B., Iowa State College, Ames, Iowa.
Krall, John A., Iowa State College, Ames, Iowa.
Lechner, H. J., Iowa State College, Ames, Iowa.
Leth, Robert J., University of Idaho, Moscow, Idaho.
Maughan, Howard J., Experiment Station, Logan, Utah.
Olson, P. J., University Farm, St. Paul, Minn.
Potter, Ralph S., Iowa State College, Ames, Iowa.
Reed, H. R., Yuma Field Station, Bard, Cal.
Reid, Harold W., Iowa State College, Ames, Iowa.
Reinholt, Martin, Agricultural College, N. Dak.
Simard, J. A., Box 211, Quebec City, Quebec, Canada.
Stewart, Geo., Dept. Agron., Agricultural College, Logan, Utah.
Stoa, Theodore E., Agricultural College, N. Dak.
Thomas, Melvin, Agricultural College, N. Dak.
Wentz, John B., Bellefourche Expt. Farm, Newell, S. Dak.

Members Resigned.

Edward C. Johnson, Edward R. Minns, A. L. Thompson.

Members Lapsed.

Basil M. Benzin,	E. L. Hsieh,	J. M. Napier,
J. Stanford Brown,	Thomas F. Hunt,	A. W. Palm,
Alex. Carlyle,	T. E. Keitt,	W. R. Porter,
George Dunlop,	Franz E. F. Krause,	F. C. Quereau,
Robert J. Evans,	J. G. Lill,	J. H. Reisner,
W. H. Frazier,	R. S. Mackintosh,	H. M. Sanderson,
L. F. Gieseker,	C. F. Marbut,	C. G. Selvig,
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Deatrick, Eugene P., 708 E. Seneca St., Ithaca, N. Y.
Ewing, E. C., Scott, Miss.
Olson, M. E., Soils Section, Iowa State College, Ames, Iowa.
Young, Yungyen, Nanyang Middle School, Shanghai, China.

NOTES AND NEWS.

A. T. Anders, a scientific assistant in the office of cotton breeding, U. S. Department of Agriculture, died suddenly in Washington, D. C., on April 3. Mr. Anders had undergone an operation for appendicitis a few days previously and was apparently recovering rapidly, when heart failure caused his death practically without warning.

Knute Espe has been appointed an assistant in soil survey work at the Iowa station.

E. C. Ewing, formerly head of the department of cotton breeding at the Mississippi station, is now in charge of the experimental department recently established by the Mississippi Delta Planting Co. at Scott, Miss. H. B. Brown, formerly professor of botany and forestry of the Mississippi college, has succeeded Mr. Ewing in the cotton work at the station.

Walter L. Latshaw has been appointed assistant in soil analysis at the Kansas station.

E. R. Lloyd, director of the Mississippi station, also has been made director of extension work. J. R. Ricks, agronomist, has been made vice-director in addition to his other duties.

Yungyen Young, who has been pursuing post-graduate studies at the University of Illinois, has been recalled to his native country, China. He is now located at the Nanyang Middle School, Shanghai.

Recent changes and appointments in the office of cereal investigations, U. S. Department of Agriculture, include the transfer of T. R. Stanton, formerly assistant in cereal investigations on the Arlington Experimental Farm, to be assistant in oat investigations with headquarters at Washington, D. C.; A. D. Ellison, to the Arlington Experimental Farm; *vice* T. R. Stanton; J. W. Jones, to the Nephi substation, Nephi, Utah, *vice* A. D. Ellison; and the appointment of V. H. Florell as scientific assistant at the Cheyenne Experiment Farm, Archer, Wyo., *vice* J. W. Jones.

The second Pan-American Scientific Congress will hold its sessions in Washington, D. C., December 27, 1915, to January 8, 1916. A wide range of scientific subjects will be discussed by the nine sections of the congress. Section III, Conservation of Natural Resources, Agriculture, Irrigation, and Forestry, and Section IV, Education, are of particular interest to members of the American Society of Agronomy. The members of the congress consist of (1) the

official delegates of the countries represented; (2) representatives of universities, institutes, societies and scientific bodies; and (3) individuals who may be invited by the executive committee. The preliminary program may be obtained from Mr. William Phillips, Third Assistant Secretary of State, Washington, D. C., who is chairman of the executive committee.

Meeting of the Washington Section.

The eighth regular meeting of the Washington (D. C.) Section of the American Society of Agronomy was held at the Cosmos Club on March 9, 1915, with an attendance of about 40 members and guests. Dr. W. W. Stockberger presented an interesting illustrated statistical paper entitled "Variation in Plat Yields of Hops." In this paper the yields of individual hop plants in a field in California for a series of years were tabulated in different groups. The object of the tabulations was to determine whether or not individual variations were constant from year to year and also to determine the variations in yield in different parts of the field preliminary to starting some fertilizer tests. "Natural Wheat-Rye Hybrids" was the title of a brief paper by Dr. C. E. Leighty, in which illustrations and descriptions of an artificial and several natural wheat-rye hybrids were presented. Dr. L. J. Briggs, who attended the meetings of the British Association of Science in Australasia last summer, talked on "Some Phases of Agriculture in New Zealand." Numerous excellent views of field and pastoral scenes in New Zealand were shown, and much interesting information was given regarding agricultural conditions there.

Department of Agriculture Appropriations for 1916.

The appropriation act for the Federal Department of Agriculture for the fiscal year beginning July 1, 1915, carries a total of $22,971,782, an amount $3,105,950 in excess of the appropriation for the previous year. The new appropriation, however, contains a provision for an emergency fund of $2,500,000 for fighting contagious diseases of animals (foot-and-mouth disease, rinderpest, etc.), which has not previously been included, so that the actual increase is only $605,950. The total appropriation just named, however, does not include the $1,080,000 available under the Smith-Lever act for agricultural extension, the permanent annual appropriation of $3,000,000 for meat inspection, or the $500,000 for the publication of bulletins and reports. The bill makes provision for the reorganization of the Department's activities as outlined in an earlier number of the Journal.

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A COMPARATIVE STUDY OF THE EFFECT OF CUMARIN AND VANILLIN ON WHEAT GROWN IN SOIL, SAND, AND WATER CULTURES.[1]

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(Contribution from the Department of Soil Technology, Cornell University.)

THE PRESENT STATUS OF THE THEORY OF SOIL TOXICITY.

INTRODUCTION.

The theory of soil toxicity dates from the time of De Candolle. Believing that the experiments of Macaire,[2] which were carried out at his suggestion, proved that plant roots secrete under normal conditions certain organic substances, which in the case of the bean were found to be harmful to the plant that produced them but beneficial to other plants, De Candolle came to consider these root secretions of universal significance in practical agriculture. He proposed to explain the necessity for crop rotation as based on the fact that plants excrete through their roots certain substances that are deleterious to

[1] A thesis submitted to the faculty of the Graduate School of Cornell University in partial fulfillment of the requirements for the degree of Doctor of Philosophy by Jehiel Davidson, B. Sc. Ithaca, N. Y., June, 1914. Received for publication March 30, 1915.

[2] Macaire, Memoire pour Servir a L'Histoire des Assolemens, Ann. de Chim. et Phys., 52 (1833), p. 225–240. De Candolle, A. P., Physiologie Vegetale, p. 248–251. Paris, 1832.

the same plants or their near relatives, but which are beneficial to other plants more or less distantly related to them.[3]

Liebig[4] considered De Candolle's theory of crop rotations "as resting on a firm basis" and placed full reliance in the experiments of Macaire. Although he interpreted the views of both of them in the light of his favorite plant-food theory, he considered the conversion of the injurious excrements of plants into humus as a matter of great importance to soil fertility.

The experiments of Macaire which constituted the principal evidence in favor of harmful root secretions, as well as of root secretions in general, were proved to be erroneous by Braconnot[5] and others, and De Candolle's views lost their adherents and were forgotten under the dominance of Liebig's mineral theory.

The theory of soil toxicity has been brought to the front again by the Federal Bureau of Soils. It has been modified and broadened. Harmful root excretions and toxic organic substances in general account, according to their views, not only for the inability of a soil to grow the same crop successively for a number of years, but also for the infertility of poor soils in general. They oppose the theory of soil toxicity to Liebig's mineral theory, which in its principal features still has a hold on the minds of the majority of agricultural investigators. To these investigators, plant food, whether of mineral or of organic origin, whether produced by physical, chemical or biological agencies, whether found in the soil originally or introduced in the form of manures and fertilizers, is still the principal key to soil fertility.

Character of the Evidence in Favor of the Theory of Soil Toxicity.

The investigators in the Bureau of Soils have brought forward a considerable amount of evidence in support of their views. The evidence may be divided in two groups. One follows the trail of De Candolle and deals with root secretions, the other deals with the presence in the soil of toxic organic substances in general. It is all, however, of indirect nature and, like all indirect evidence, it holds good only so long as the phenomena on which it is based can be explained only by the theory which it supports.

[3] De Candolle, l. c., pp. 1474–75 and pp. 1493–1520.

[4] Liebig, Justus, Chemistry in its Application to Agriculture and Physiology, p. 163–174. Cambridge, 1842.

[5] Braconnot, H., Recherches sur l'Influence des Plantes sur le Sol, Ann. de Chim. et Phys., 62 (1839), p. 27–40.

Any other explanation which could be offered to account for the phenomena that serve as evidence in favor of the theory of soil toxicity would rob the evidence of its principal force and relegate the theory in question to a mere hypothesis, more or less plausible. It remains to be seen whether the evidence brought forward stands the criterion of indirect evidence, that is, whether the phenomena on which it is based can not be explained in any way except by the theory of soil toxicity.

Crop Rotations.

No new evidence has been brought forward since the time of De Candolle to substantiate the view that the failure to grow one crop successfully year after year is due to autotoxic substances secreted by the plant roots. The experiments of Macaire which formed the principal basis of De Candolle's theory, as stated above, have been found to be entirely erroneous. The experiments at Rothamsted[6] where wheat was grown successfully for fifty years in succession would tend to serve as evidence against the secretion of autotoxic substances by the roots. Up to the present time no root secretions except carbon dioxide have been definitely established.

Passing from facts to general considerations, we can easily come to the conclusion that autotoxic excreta in plants are inconsistent with the general laws of adaptation. We could conceive of excreta which are harmful to other plants as a weapon in the struggle for survival, as was suggested by Humboldt and Plenk[7] with reference to the existence of plant associations. It is hard, however, to conceive how an autotoxic excretion helped the plants possessing it to survive in the struggle for existence or at least how it did not interfere with them in this struggle.

As to the explanation of the beneficial effects of crop rotations, there are a great number of other factors besides autotoxic secreta which may account for them. These include the different methods of cultivation associated with the different crops in the rotations, the different methods of feeding, the difference in the microbiological flora which accompanies the different crops, etc.

Effect of Grass on Trees.

It has been observed on the Woburn Experimental Fruit Farm that grass was injurious to fruit trees. The effect of the grass was so

[6] Gilbert, J. H., Agricultural Investigations at Rothamsted, U. S. Dept. Agr., Office of Exp. Sta. Bul. 22, p. 146–171.

[7] De Candolle, l. c., p. 1474–76.

singular in its character that, according to the authors of the reports, every tree which was grassed over could be easily recognized even if the surface soil were entirely hidden from view.

"The coloring matters in the leaves, bark and fruit are affected in a manner which is not produced by any other form of ill treatment. The bark is pale and much yellower than in a healthy tree; the buds burst at a comparatively early date; and the foliage always exhibits a pale sickly hue, which is quite different from that of trees in the open ground. The autumn tints appear some two weeks earlier than in healthy trees. The fruit, when there is any, shows similar peculiarities of coloring; in case of green apples, for instance, the color is changed either to waxy yellow or to brilliant red."[8]

The ill effects of the grass were shown with reference to old trees as well as to newly planted trees. The effects on the latter were in many cases fatal, leading to death after the first season.

The possible reasons for the ill effects of the grass that suggested themselves were deficiency in moisture due to excessive loss of water caused by transpiration from the grass, deficiency in plant nutrients due to competition of the grass, lack of aeration, excessive amounts of carbon dioxide due to respiration of the grass roots, and differences in temperature. The authors of the reports of the Woburn Fruit Farm checked up the influence of every one of these factors and found that none of them could be considered responsible for the characteristic ill effects on the trees produced by the grass. They therefore reached the conclusion that the effect of the grass was due to some direct poisonous action produced by the grass, either through the agency of micro-organisms for the development of which it offers favorable conditions, or directly by secreting some poisonous substance through the roots.

On a closer examination, however, of the methods used in the experiments which were carried out with the object of checking up the individual influences of the factors mentioned above, we find that they were not thorough enough to justify the negative attitude of the experimenters toward these factors with reference to their instrumentality in the ill effects caused by the grass on the apple trees.

To check up the influence of the moisture factor, the experimenters supplied water artificially to the grassed-over trees and found no improvement. They grew trees in closed pots with a supply of moisture limited to such an extent the trees showed signs of actual suffering from thirst, but the peculiar grass effects could not be observed, although the vigor of the trees was markedly impaired. They could

[8] Pickering, S. P., The Effects of Grass on Apple Trees, Jour. Royal Agr. Soc. of England, 64 (1903), p. 373.

not observe any difference in the appearance of the grassed-over trees between dry and wet seasons. The grassed-over trees never showed any indication of actual suffering from thirst.[9]

As the soil on the experimental farm was shallow, there is a question how much and for how long the artificial applications of water which were made weekly and the rains of the wet seasons increased the actual moisture content of the soil. There is also doubt as to how much of the increase was left at the disposal of the trees, taking in consideration the fact that grass is such a powerful competitor for moisture. That the trees in the closed pots did not show the characteristic peculiarities of the grassed-over trees might be due to the fact that the trees in the pots showed actual signs of suffering from thirst, while the water supply of the grassed-over trees was not deficient to that extent. Would it not have been more direct to have grown trees in pots together with grass and to have had the moisture properly controlled by weighings at regular intervals?

In order to check up the aeration factor, the soil under the grassed-over trees was aerated in various ways and the soil under trees grown without grass was prevented from being aerated as effectively as possible. No change was observed by the experimenters in the behavior of the trees under either treatment.

However, no mention is made of how effective the artificial aeration proved to be, that is, whether or not the soil air was actually enriched in oxygen. It further remains questionable whether the grass again did not prove to be a more powerful competitor for the increase in oxygen, if any. With reference to the experiments in which aeration was prevented, it is possible that in the absence of any competition, the oxygen supplied in the water which came from aerated sources might have been sufficient to supply the needs of the trees.

The plant-food factor was checked up by growing a two-year-old tree in washed sand which contained very insignificant amounts of the nutrient elements. The tree made good normal growth for a whole year and survived during the second season without showing any of the characteristic grass effects. The experimenters concluded that the deficiency in plant food is not the factor which is responsible for the grass effects, since practically entire lack of plant food failed to produce effects similar to those produced by the grass.[10]

There is some question, however, whether there was an entire lack of plant food. It is possible that the amount of plant food contained in the water with which the tree was supplied was sufficient to support

[9] Pickering, S. P., l. c.

[10] Pickering, S. P., l. c.

the normal growth of a two-year-old tree for one season. It is further possible that the deficiency in total plant food is less injurious than the deficiency in one element of plant food, which might have been the case of the grassed-over trees. Would it not have been more to the point, as in the case of the moisture experiment, to have grown the two-year-old tree together with grass in the presence of an abundant supply of balanced plant food?

The principal fallacy of the experiments, however, lies in the fact that the experimenters were trying to obtain the peculiar grass effects from each of the factors singly, while these effects might have been the result of certain combinations of these factors. The peculiar grass effects as they are described by the Woburn investigators could have been ascribed with a great degree of plausibility to the combined influence of a deficiency in moisture and nitrates. This possibility is strengthened by the fact that when the soil around the trees was planted to clover, the color effects were missing.

The inability of oak trees to advance into the socalled "oak openings" (grassy tracts) which were found in the natural oak forests of Ohio and Indiana[11] and the antagonisms existing between butternut trees and shrubby cinquefoil, reported by Jones and Morse,[12] as well as the antagonism between peach trees and several grasses reported by Hedrick,[13] are phenomena similar to those observed on the Woburn Fruit Farm. Toxic excreta or poisonous action in general is not the only possibility which may be offered in their explanation.

Wheat Grown in Association with Tree Seedlings.

Germinated wheat seedlings were grown by C. A. Jensen[14] in paraffined pots in association with seedlings of pine, maple, dogwood and cherry. The same number of wheat seedlings were planted in every pot. Successive crops of wheat were grown one after another for periods of two to three weeks. One of the pine seedlings died during the first crop of wheat but the pot was not discarded and received the same treatment as the other pots. Table 1 (taken intact from Bureau of Soils Bulletin No. 40) gives the relative green weights of the wheat crops.

[11] Schreiner, Oswald, and Reed, Howard S., Some Factors Influencing Soil Fertility, U. S. Dept. Agr., Bur. Soils Bul. No. 40, p. 37. 1907.

[12] Jones, L. R., and Morse, W. J., Ann. Rep. Vt. Agr. Expt. Sta. 16 (1903), p. 173–190. U. S. Dept. Agr., Bur. Soils Bul. No. 40, p. 17.

[13] Hedrick, U. P. Proc. Soc. Hort. Sci., 1905, p. 72–82. U. S. Dept. Agr., Bur. Soils Bul. No. 40, p. 17.

[14] Schreiner, Oswald, and Reed, Howard S., l. c., p. 18–19.

TABLE 1.—*Relative Green Weights of Wheat Crops Grown in Association With Tree Seedlings.*

Date of Harvesting.	June 29.	July 12.	Aug. 1.	Aug. 22.	Sept. 6.	Oct. 13.	Oct 29.	Nov. 19.	Dec. 6.	Ave. First Six Crops.	Ave. Last Three Crops.
Control	100	100	100	100	100	100	100	100	100	100	100
Maple 1	76	65	86	68	67	86	92	91	96	74	93
" 2	44	86	75	59	71	79	90	75	109	71	91
" 3	21	83	72	72	79	84	81	103	92	70	92
Dogwood 1	92	96	76	84	71	65	85	68	115	81	89
" 2	86	79	63	86	75	73	84	107	88	78	93
Cherry	81	91	102	91	71	94	88	102	93	88	94
Tulip	21	106	62	77	68	100	77	109	103	75	96
Pine	55	69	68	52	54	80	62	83	60	63	68
Pine (dead)	62	96	85	91	80	89	97	96	67	84	87

Table 1 shows that the wheat crops suffered from association with the tree seedlings. The depressing effects of the tree seedlings decreased toward autumn, however, as is noticeable especially when the last two columns are compared.

The authors of Bureau of Soils Bulletin No. 40 believe that the depressing effects of the tree seedlings were due to toxic excreta produced by their roots. They believe that this view is borne out by the entire behavior of the experiment. The increase of the relative yields toward autumn coincides with the period when the trees enter upon their seasonal rest and was due, according to them, to the fact that the toxic excreta were diminished, together with the decrease of the general physiological activity of the deciduous trees. The increase in the yield of the wheat crops grown in association with dogwood was less because it was the last to shed its leaves. The pot containing the living pine tree did not show any increase in the last three crops. The pot containing the dead pine gave better yields than the other tree pots but inferior to those of the controls. The authors argue that the depressing effects of the trees could not be due to depletion of plant food since "if the trees had removed sufficient plant food to starve the wheat plants in the summer period, the increased yield toward autumn would be incapable of explanation."

However, the figures presented in the table do not show any absolute increase in yield for the tree pots toward autumn. They only show that they were nearer to the yield of the controls. It is possible that the better crops of the controls had removed toward the end of the summer nearly as much plant food as the wheat crops together with the trees in the other pots and this is why there was less difference in the respective yields. Supposing that the yields actually increased toward autumn, the possibility that the depressing effect of

the trees was a plant food phenomenon is not at all excluded. The status of available plant food in the soil is dynamic in character. Plant food is continually being manufactured in the soil. The same decrease in the physiological activity of the trees during the period of rest which, according to the authors, caused a decrease in root excreta, also caused a decrease in plant food assimilation, and the increased yield of wheat in the tree pots might have been due to the lessened competition of the trees for plant food.

Fairy Rings.

This fanciful name is given to rings of grass in pastures or meadows which are markedly darker in color and more luxuriant in growth. In close proximity to the rings, on the outside, various fungi are always found, so that there are really two rings, a ring of grass and a ring of fungi. The diameter of the concentric rings increases every year and it is generally assumed that the smallest ring is preceded by a single point or by a small continuous area.

Schreiner and Reed[15] are evidently inclined to interpret this phenomenon in the sense of De Candolle's theory which Way[16] considers "by far the most scientific and most intelligent solution of the question," but which he does not accept. The phenomenon of the fairy rings would just fit in De Candolle's theory. The fungi recede because they excrete certain substances which are harmful to themselves but which are beneficial to grass. The excreta beneficial to the grass do not extend very far and therefore the luxuriant growth of grass follows the fungi in the form of an inner concentric ring.

Way ignores the fact that the fungi do not grow inside of the ring and tries to explain the luxuriant growth of the grass. The fungi, according to Way, are good collectors of the mineral plant food elements. When they die they fertilize the soil in the immediate vicinity and so cause the luxuriant growth of grass of the ring.

The authors of Bulletin No. 40 do not concern themselves with the grass, but with the fact that the fungi do not grow inside of the ring. This fact serves, according to them, as evidence in favor of autotoxic plant excreta. The failure of the fungi to grow inside of the ring can not, they say, be due to depletion in plant food, since the analysis of the soil inside and outside of the rings by Lawes and Gilbert showed too slight differences. Inside of the ring the percentage of nitrogen was 0.247 and of carbon, 2.78; outside of the

[15] L. c., p. 37.

[16] Way, J. T., On the Fairy Rings of Pastures, etc., Jour. Royal Agr. Soc., 7 (1846), pp. 549–552.

ring the percentage of nitrogen was 0.281 and of carbon 3.30. The amounts of carbon and nitrogen, however, are consistently higher outside of the ring than inside. It is possible that the difference is limited to the available organic materials on which fungi grow and, small as it is, it may be a factor which determines the growth of the fungi.

Gilbert[17] interpreted the behavior of the grass and the fungi in the fairy rings entirely in the sense of the plant-food theory.

There is another objection to the use of fairy rings as evidence in favor of autotoxic plant excreta. We are hardly justified in drawing an analogy between heterotrophic and autotrophic plants, as we do know for certain that the heterotrophic plants do excrete certain organic substances such as enzymes, and that these substances are of vital significance in the economy of their nutrition. On the other hand, we do not know of any secretions by roots of autotrophic plants except carbon dioxid.

The Diminished Yield of Succeeding Crops.

A number of experiments with wheat in paraffined pots were conducted[18] to show that the diminished yield of succeeding crops is due not to depletion of plant food but to toxic excreta produced by the previous crop. The crops were grown for periods of three or four weeks. The results show invariably that the succeeding crops were considerably lower than the first crops. They further show that the addition of fertilizers did not change to any considerable extent the proportional relations between the first and the succeeding crops, and that the addition of cowpeas and lime was more effective than the addition of mineral fertilizers.

Since young crops could not have removed sufficient plant food to account for the marked decline of the succeeding crop and since the addition of cowpeas and lime which do not furnish immediate plant food proved to be more effective than the addition of direct plant food in the form of fertilizers, the authors conclude that the depressive effect of the previous crop was due to toxic excreta. As further evidence in this connection, they consider the fact that, as shown by their experiments, the mere germination of seeds in a soil is already detrimental to the succeeding crop. Similar results were obtained by Livingston[19] and his associates with soil and washed quartz sand.

[17] Gilbert, J. H., Note on the Occurrence of Fairy Rings, Jour. of Linnean Soc., 15 (1877), pp. 17–24.

[18] Schreiner and Reed, l. c., p. 10–15.

[19] Livingston, Burton Edward, Britton, J. C., and Reid, F. R., Studies on the Properties of an Unproductive Soil, U. S. Dept. Agr., Bur. Soils Bul. No. 28. 1905

The authors of this bulletin do not make it clear whether they consider the evidence brought forward in this connection as substantiating the "toxic" interpretation of crop rotations, that is, whether they would expect different results if several crops were used in a rotation under the same conditions.

The results of these experiments would really tend to show that the depressing effects of the previous crops were not due to depletion of plant food. They do not show conclusively, however, that the inferior yields were due to toxic root excreta nor that the secretion of toxic substances might be a factor under natural field conditions. The experiments were conducted under such unnatural conditions that in many of them the depressing effects might have been due to physical deterioration of the soil. This interpretation would be in harmony with the fact that lime and cowpeas had a more decided ameliorating effect than fertilizers.

It is, however, possible that in all the results here reported the depressing effects were due to conditions associated with seed germination, since the crops in all cases were grown only for short periods.

The phenomena of seed germination are so entirely different from conditions of plant growth after the plant begins to draw its nutrition from the surrounding medium that they ought to be considered separately. The metabolic changes, both destructive and constructive, during the period of seed germination are so rapid, so many different enzymes are involved in the transformation of the products stored up in the seeds, and so much organic material is made available for the growing embryo that the products of seed germination may become harmful to plants when they accumulate, either directly or through the agency of micro-organisms which they may attract.

However, the phenomena associated with the processes of seed germination are a natural stage in the evolution of plants. Each step in the development of the plant is adapted to the corresponding stages of the seed metabolism and its normal growth is, therefore, not interfered with by the products of germination of its mother seed under natural conditions. As to the effect on the succeeding crop, the products of metabolism in the process of seed germination are of such unstable nature that they can hardly be expected to last until the next normal crop and can hardly be a factor in soil fertility under normal conditions when crops are grown to maturity.

Wheat Seedlings Grown in Agar.[20]

Segments of glass tubing about three centimeters long and having an internal diameter of 6 to 8 millimeters were fastened in a vertical position to a glass rod at intervals of 2 to 3 millimeters. The segmented tubes were placed in small jars and melted agar was poured in them till its level reached the surface of the upper segment. When the agar cooled down to 35° to 38° C., wheat seedlings were planted in the upper segments of the segmented tubes.

About 53 percent of the seedlings grew out through the openings of the segmented tubes into the surrounding agar. When the experiments were repeated with agar in which seedlings had been previously allowed to grow a smaller percentage of the roots curved into the segmented openings. When the same experiments were carried out in such a way as to eliminate the geotropic tendency of the roots by the use of a klinostat, a greater percentage of roots curved out into the openings. When fresh agar was used inside of the segmented tubes and agar in which seedlings had previously been grown outside of them, the percentage of curvatures was smaller. On the other hand, a larger percentage of curvatures was obtained when used agar was placed inside of the segmented tubes and fresh agar outside of them. Certain relationships were obtained with reference to the behavior of wheat seedlings when agar in which corn, cowpeas and oats had been grown was used outside and inside of the segmented tubes.

These facts tend to show, according to the authors, that the roots of the plants included in the experiment excrete certain substances deleterious to themselves, but less or not at all deleterious to other plants, the tendency to grow into the openings being due to the stimulus of negative chemotropism, a tendency to grow away from a harmful substance.

A closer examination of the figures presented in connection with these experiments shows so much variation between the individual experiments that we are hardly justified in considering the averages as the expression of the general tendency of the phenomena.

The curving into the openings might have been due to a cause of a physical nature, the slight tendency of the averages to behave in the expected direction being simply accidental. The growing tip, as it is generally known, exerts a considerable pressure. This perhaps forced the agar in the narrow segments into the openings and the roots were carried along with the agar, or the curving into the openings might have been due to the general spreading habits of the root system.

[20] Schreiner and Reed, l. c., p. 23–36.

If, however, the curving into the openings was really due to differences between the agar in the segmented tubes and the outside agar, the theory of toxic excreta is not the only possible explanation. The tendency to curve into the openings might have been due to water relations, there being more available water outside of the narrow segmented tube. This possibility becomes more plausible when we take into consideration the fact that while chemotropism in higher plants has not been definitely established, hydrotropism, or the movement toward water, is a well-known phenomenon.[21]

Behavior of Wheat Seedlings in Water Extracts of Soil.[22]

The behavior of soil extracts is brought forward as evidence in favor of the existence of toxic substances in soils, regardless of their origin.

It was found that a poor soil extract yields poorer crops than distilled water. The depressing effects of the extract could not be due to lack of plant food, since it contains more of it than the distilled water. When an extract of a poor soil is diluted the yield is improved, notwithstanding the fact that the diluted extract contains less plant food. A case is reported in which the poor properties of a soil extract were transferred to its distillate, which would tend to indicate the presence of some volatile toxic substances. When a poor soil extract was used in making up a balanced solution the yields obtained were inferior to those which were obtained when the same balanced nutrient solution was made up with distilled water. The addition of substances which have no nutritive value at all, as pyrogallol, ferric hydrate and carbon black, improves greatly the crop productivity of the poor soil extract. The beneficial effects of these substances is ascribed to their power of absorbing the toxic substances present in the extracts.

All these facts would tend to show that there is something in the extracts of the poor soils which interferes with plant growth, although some of these facts do not bear necessarily on the presence of toxic bodies. It was found, for instance, that the addition of solids, as carbon black, ferric hydrate, etc., improves a good soil extract also, although not to so great an extent as it improves a poor soil extract. It is possible that the action of the added solid is absorptive, but the good soil extract also contains comparatively small amounts of toxic substances and it is, therefore, also improved by the addition of ab-

[21] Jost, L., Lectures on Plant Physiology, pp. 484–485. Oxford, 1907.

[22] U. S. Dept. of Agr., Bureau of Soils Bul. 28, 36, and 40.

sorbing agents. It is, however, also possible that the effect of the solid is due to some other cause, the action perhaps being on the plant rather than on the medium. It is possible, for instance, that the solids stimulate a response in plant roots just as gravity does (geotropism). If so, the different extent of the effects of the solid on the poor and good soil extract would be due either to the different properties of the extracts which affect that response differently, or to the limits of possible improvement.

As to the effects of dilution on the productive capacity of the poor soil extract, the results obtained lose much of their force as a proof in favor of the theory of soil toxicity because it has never been tried on a good soil extract. It would perhaps be found that good soil extracts would also be improved by dilution and it would then be possible to suggest some other explanation of the beneficial effect of dilution in addition to the one based on the dilution of the toxic substances.

The yields in the experiments with soil extracts were generally measured by transpiration, which is not always a reliable indicator of plant growth. The plants were grown only for periods of two to three weeks, under which condition too much significance can not be attached to differences in yield if they are not striking, as was the case in many of these experiments.

The results obtained with soil extracts in general could hardly be considered as due to the same factors which are operative in the poor soils from which they were prepared under field conditions. This is because the extracts were prepared in such a different manner for the natural soil solution (excess of solvent, shaking, etc.), and since the soil, as it was shown, has such an ameliorating influence on the poor properties of a liquid medium, even when present in very small quantities.[23]

Isolation of Toxic Substances from Soils.

A number of organic compounds have been isolated by Schreiner and Shorey[24] from different soils and some of them have proved to be toxic to plants in water cultures, as picoline carboxylic acid and dihydroxystearic acid. With reference to picoline carboxylic acid, the authors have admitted that it was hardly a factor in soil fertility.[25] They think, however, that dihydroxystearic acid is directly responsible for the poor yields of the poor soils from which it has been isolated, since it shows depressing effects in water cultures even when

[23] Livingston, B. E., et al., l. c., p. 35.

[24] Schreiner, Oswald, and Shorey, Edmund C., The Isolation of Harmful Organic Substances from Soils, U. S. Dept. Agr., Bur. Soils Bul. No. 53, 1909.

[25] L. c., p. 47.

present in concentrations as low as 20 parts per million. It is questionable, however, as previously pointed out, whether conclusions with reference to actual field conditions can be drawn from results obtained in water cultures.

Dihydroxystearic acid has been isolated from good soils as well as from poor soils, although much more frequently from the latter than from the former. It has been admitted by Schreiner[26] that dihydroxystearic acid is perhaps not responsible for the low productive capacity of the poor soils from which it has been isolated and that it is possible that its presence is a result of the same conditions which render the soils poor. Furthermore, the very presence of dihydroxystearic acid in soils from which it has been isolated is not definitely established as it is possible that it is formed during the process of extraction.

Summary.

It is apparent from the foregoing analysis that the evidence which is offered in favor of the theory of soil toxicity is neither direct nor conclusive. The facts on which it is based can be interpreted in a variety of ways other than the existence of toxic substances.

The question would be considered definitely settled if toxic substances isolated from a poor soil, when applied in the same quantity in which they are there present, caused a soil which does not contain them to produce a poor crop similar to that produced by the poor soil.

Indirect or circumstantial evidence is of less value in problems of soil fertility than in many other problems. So many factors known and unknown affect the soil that several interpretations of the same phenomena are frequently possible. The real significance of these phenomena may often escape us because of our lack of knowledge of the processes taking place in the soil.

(*To be concluded in the September–October Journal.*)

[26] Schreiner, O., and Lathrop, E. C., Dihydroxystearic Acid in Good and Poor Soils, Jour. Amer. Chem. Soc., 33 (1911), p. 1412–1417.

SEED VALUES OF MAIZE KERNELS, BUTTS, MIDDLES AND TIPS.[1]

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INTRODUCTION.

Many efforts have been made to determine the relative value as seed of the kernels from the different parts of the ear of Indian corn, but the results have appeared so contradictory that little progress has been made toward any definite conclusions. Generally speaking, the directions given have been to throw away the butts and tips of the ear and to plant only seed from the middle portion. A variety of reasons have been advanced for this practice.

In connection with the preparation of a bibliography and index of the literature relating to maize, there has been an opportunity to review the work which has been done along this line. This canvass of the subject was undertaken at the suggestion of Mr. G. N. Collins, who considered it worth while to determine how far the apparently contradictory results of the different experiments could be reconciled by taking into account the fact that the silks of the kernels from the tip end of the ear are the last to appear. They often are not exserted until all the pollen from the plant has been shed, hence the tip kernels are more likely than the others to escape self-fertilization, with the accompanying decrease in vigor and productiveness. During the examination of the literature it was learned that Hunt (1909)[2] had suggested the same explanation, but he seems to have made no attempt to determine whether the experimental data would support this interpretation.

In this paper all of the data that have been given by the different experimenters are brought together, arranged for comparison, and reviewed, to see whether any definite differences have been shown, and if so, whether these could be ascribed reasonably to the greater chances of cross-fertilization of the kernels at the ends of the ear.

[1] Received for publication February 25, 1915.

[2] Dates in parentheses refer to the bibliography at the end of the paper.

Early Opinions on the Use of Tip Seed.

For more than a century and a quarter directions have been given as to what part of the ear of corn should be used for seed. Parmentier (1785), Harasti (1793), Des Michels (1829) and Bonafous (1836) all warn against the use of kernels from the tip of the ear for seed, as they state such kernels are not so "well nourished" as the others and are likely to produce weak plants. However, when Des Michels adds to the above statement, as an additional reason for not planting tip kernels, "because often they have not been fertilized," we begin to suspect that he was not reporting the results of experiments or accurate observation. It was probably common practice then as now to use the kernels with the best appearance for seed, and these are undoubtedly found on the middle of the ear if uniformity of size and shape is the criterion. Modern practices of careful selection and testing of seed make it desirable to use all of the seed from the best ears. Certainly none of the best seed should be discarded unless there is a practical reason for doing so.

Popular Objections to the Use of Tip Seed.

The introduction of modern corn-planting machinery strengthened the practice of discarding the tips for seed. When using a corn planter, a uniform stand can only be obtained with seed of approximately the same size and shape, so that the small tip and distorted butt kernels seem undesirable. It has thus become the practice in many sections to discard the butts and tips of the ear and to use only the kernels from the middle of the ear for planting. A great deal has been written about the loss occasioned by an irregular stand, but an experiment carried out in Nebraska by Montgomery (1909) shows that this loss has been overestimated. The data gathered by Montgomery show that ordinary variation in rate of dropping will have little or no effect on the yield per acre, as the plants contiguous to any unused space profit materially by the increased nutriment at their disposal. So we must look further for a reason for discarding the butts and tips of the ears.

The next objection urged against the use of tip seed is that the strongest plants come from the largest and heaviest seeds and the smallness of tip kernels makes them undesirable for planting. Georgeson, Burtis and Shelton (1891) report an experiment planned to settle the question whether a corn plant grown from a small kernel is just as thrifty and will yield as well as one grown from a large seed. Ten twentieth-acre plats were devoted to this experiment,

which was conducted with the St. Charles dent corn. The results plainly show that there is practically no difference in the resulting plant whether the seed kernels are large or small, provided they are sound. Sturtevant (1883) says:

"Small kernels selected for their diminutive size from a normal ear, yield plants and crops not only equal but curiously enough often superior to those grown from kernels of normal size. In one case where very small shrivelled kernels of Waushakum corn were collected from a tassel where abnormally borne, and used for seed, the crop was very superior in quality and yield and every ear perfect in type. Sixteen seed yielded eighteen good ears from six to nine inches long, and four unmerchantable ears. So far as our observations at present extend, the small size of the tip kernels offers no objection for certainty of growth or yield but the hybridization from plants from large seed may possibly vitiate our trial."

Sturtevant (1885) later carried out an experiment in regard to the effect of the size of the seed on the resulting plant. The figures obtained (Table 1) show very little difference between the crops from the two kinds of seed.

TABLE 1. *Relative Yield from Large and Small Seed (after Sturtevant).*

	Number of Good Ears.	Number of Poor Ears.	Bushels of Good Ears.	Bushels of Poor Ears.	Average Weight of Ears.
					Ounces.
Large seed.....	14,360	1,630	69.7	2.1	6.21
Small seed.....	14,390	1,950	67.9	2.1	6.04

FIRST RECORDED EXPERIMENTS ON THE SUBJECT.

In 1857 we have the first report of a series of experiments as to the best part of the ear to plant. These experiments were carried on for ten successive years to find out the relative merits of butt, tip and middle kernels for seed. Flint (1857) says:

"A farmer planted only the corn from the small end of the ears, choosing such as were well filled out; then only from the middle of the ears; then only from the big ends. After ten years he found that in seven years of the ten the crop from the small end was the largest and the best."

Two years later Flint (1859) says:

"In selecting corn for seed the tips of the ears are thought to be best, and that part near the butt end of the ear next in value. . . . The experiment of planting seed taken from different parts of the ear has been repeatedly tried, and the result has almost uniformly been better from that taken near the tips, however contrary it may be to the theories received, in regard to the full and complete development and perfection of seed."

The first experiments to determine the relative merits of butt, middle and tip seed which were carefully planned and fully reported were those of E. L. Sturtevant of the New York Agricultural Experiment Station. Of these experiments Hall (1907) says:

"Probably few experiments in field crops ever excited more comment than those carried on at the station in 1882, '83, '84, and '85, by which it was established that there is practically no difference in germinative ability or crop-producing power between seed from the tip, middle or butt of the ear. The criticisms of this work ranged all the way from dogmatic assertions that the experiment was idiotic throughout, in conception, execution and conclusion, to unqualified praise of the station for demonstrating scientifically a fact that might be of great practical value to the growers of corn."

Experimental Data.

Since the experiments recorded by Flint no less than 16 sets of experiments have been made to determine this question, including those of Sturtevant just mentioned. Of these 10 have been reported in such a way as to make tabulation and comparison possible. Table 2 is the result of the tabulation. It will be seen that in every case the yield of seed taken from the middle of the ear has been represented by 100 and the relative value of the yield from the butt and tip as compard with that of the yield from the middle has been computed. In other words, the yield of butt and tip seed is expressed as a percentage of the yield of the middle seed. In the 81 different trials the yield from the butt seed averages 3 percent and that from the tip seed 5 percent greater than from the middle seed.

In addition to the 81 experiments so reported as to be comparable, North Carolina, Minnesota and Michigan have done some work along this line, but have not given particulars. Pennsylvania has done much more than Table 2 indicates, but a large part of the work was reported with insufficient data. In that state the experiments were carried on for eleven years but for four only were the results reported fully enough to enable a comparison with the results secured by others.

Definition of Butt and Tip Seed.

In considering Table 2, the question arises as to what is considered tip, and what butt seed. In one-half the experiments which were tabulated, it is stated what part of the ear was considered as butt or tip. These data are given in Table 3.

From Table 3 it is seen that Alabama, Arkansas, Kansas and New York took the extreme ends of the ear as tip and butt seed. Georgia

TABLE 2. *Summary of Experiments on Relative Yield of Seed from Butt, Middle and Tip of Maize Ears.*

Locality.	Year.	Butt.	Middle.	Tip.	Type.	Variety.	Size of Plot.	No. of Plots.
							(Acre)	
Alabama....	1896	114	100	97	Flint	Expt. Sta. Yellow	1/9	6
	1896	99	100	97	Dent	Renfro	1/9	1
	1896	151	100	131	Do.	.....	1/9	1
	1896	101	100	90	Do.	Hickory King	1/9	1
	1897	101	100	112	Flint	Expt. Sta. Yellow	1/8	2
	1898	94	100	103	Do.	Do.	.....	9
Arkansas....	1892	111	100	99	Dent	White Dent	.....	1
Georgia.....	1896	102	100	104	.....	.....	.....	2
	1900	100	100	104	Dent	Barnes' Mammoth	.....	6
	1910	107	100	111	Do.	Marlborough	.....	17
	1911	111	100	111	.....	.....	.....	17
Kansas.....	1891	102	100	84	Dent	St. Charles	1/20	1
	1891	102	100	99	Do.	Do.	1/20	1
	1891	127	100	131	Do.	Do.	1/20	1
	1891	105	100	91	Do.	Do.	1/20	1
	1891	98	100	94	Do.	Do.	1/20	1
	1892	87	100	98	.....	.....	.....	5
	1893	142	100	109	Dent	Dole 90-Day	.....	1
	1893	118	100	116	Do.	Do.	.....	1
	1893	155	100	159	Do.	Do.	.....	1
	1893	84	100	221	Do.	Do.	.....	1
	1893	100	100	75	Do.	Do.	.....	1
	1895	112	100	96	Do.	Do.	.....	5
	1896	99	100	89	.....	.....	1/10	1
	1896	107	100	101	.....	.....	1/10	1
	1896	105	100	106	.....	.....	1/10	1
Ohio.....	1886	120	100	111	Dent	.....	.....	1
	1888	99	100	95	Do.	.....	.....	3
	1889	100	100	101	Do.	.....	.....	1
	1890	117	100	114	Do.	.....	.....	2
	1891	99	100	95	Do.	.....	.....	4
	1892	96	100	103	Do.	.....	.....	3
	1893	96	100	98	Do.	.....	.....	3
	1894	99	100	106	Do.	.....	.....	3
	1895	98	100	101	Do.	.....	.....	2
	1896	94	100	85	Do.	.....	.....	2
Ontario.....	1896	104	100	102	.....	.....	.....	1
Penn. Central	1869	97	100	98	.....	.....	1/8	1
	1870	98	100	97	.....	.....	1/8	1
	1871	84	100	103	.....	.....	1/8	1
	1872	111	100	109	.....	.....	1/8	1
Western	1869	72	100	81	.....	.....	1/8	1
	1870	128	100	136	.....	.....	1/8	1
	1871	109	100	111	.....	.....	1/8	1
	1872	78	100	78	.....	.....	1/8	1
New York...	1882	134	100	134	Flint	Waushakum	.....	2
	1883	99	100	104	Do.	Do.	1/20	2
	1883	96	100	104	Do.	Do.	1/20	1
	1883	104	100	99	Do.	Do.	1/20	1
	1883	99	100	100	Do.	Do.	1/20	1
	1883	97	100	115	Do.	Do.	1/20	1

Locality.	Year.	Butt.	Middle.	Tip.	Type.	Variety.	Size of Plot.	No. of Plots.
New York...	1883	104	100	102	Do.	Do.	1/20	1
	1883	98	100	99	Do.	Do.	1/20	1
	1883	93	100	105	Do.	Do.	1/20	1
	1883	102	100	103	Do.	Do.	1/20	1
	1883	109	100	101	Do.	Do.	1/20	1
	1884	95	100	98	Do.	Do.	1/20	1
	1884	107	100	109	Do.	Do.	1/20	1
	1884	116	100	115	Do.	Do.	1/20	1
	1884	95	100	106	Do.	Do.	1/20	1
	1884	99	100	103	Do.	Do.	1/20	1
	1884	92	100	108	Do.	Do.	1/20	1
	1884	95	100	84	Do.	Do.	1/20	1
	1884	93	100	104	Do.	Do.	1/20	1
	1884	107	100	120	Do.	Do.	1/20	1
	1884	91	100	106	Do.	Do.	1/20	1
	1884	105	100	107	Do.	Do.	1/20	1
	1884	101	100	103	Do.	Do.	1/20	1
	1884	101	100	93	Do.	Do.	1/20	1
	1884	91	100	108	Do.	Do.	1/20	1
	1884	96	100	95	Do.	Do.	1/20	1
	1884	99	100	98	Do.	Do.	1/20	1
	1884	96	100	101	Do.	Do.	1/20	1
	1884	100	100	102	Do.	Do.	1/20	1
	1884	93	100	98	Do.	Do.	1/20	1
	1884	95	100	100	Do.	Do.	1/20	1
	1885	95	100	98	Do.	Do.	1/20	1
Tennessee...	1901	123	100	95	.....	.....	.....	1
Wisconsin...	1871	104	100	95	Do.	New England	.....	1
	1873	94	100	96	Do.	Do.	.....	1
	1874	102	100	113	Do.	Do.	.....	1
Means.....		103±.9	100	105±1				

shelled off one inch from end of tip and discarded these kernels, then planted ⅓ of the remainder. As New York planted the 5 tip

TABLE 3. *Part of Ear Considered as Tip and Butt in the Various Experiments.*

Locality.	Tip.	Butt.
Alabama	First inch of tip. Only sound kernels used.	First inch of butt.
Arkansas	First ⅕ of ear.	Last ⅕ of ear.
Georgia	1 inch from end of tip	2 inches of butt.
1896	shelled off and discarded. Next 2 inches planted.	
1900, 1910, 1911	1 inch from end of tip shelled off and discarded, ⅓ of remainder planted.	Last ⅓ planted.
Kansas	Extreme end of ear. Only sound kernels planted.	Extreme end of butt. Only sound kernels planted.
New York	5 tip grains [rows]	5 butt grains [rows]

and the 5 butt rows it will be seen that Georgia discarded all that part of the ear corresponding to the part which New York planted, and the results are scarcely comparable. For butt seed Georgia planted the last ⅓ of the ear, being ⅓ of the total length and including much more of the seed near the middle than any of the other experiments. In spite of these facts, in the Georgia experiments the yield from the tip seed was higher than that from either the butt or the middle seed in 3 out of 4 cases, and in the fourth case was equal to the yield of the butt seed, which was 11 percent greater than the yield from the middle seed. It is much to be regretted that Ohio, Ontario, Pennsylvania, Tennessee and Wisconsin did not indicate exactly what part of the ear was used as tip seed and what part as butt seed.

Discussion of the Experimental Data.

It is interesting to note that in the 81 trials reported in Table 2, the yield of butt seed ranges from 28 below the middle to 55 above, and the range of the yield from the tips is even larger, being from 25 below to 121 above the middles. Are these wide differences accidental, or are there conditions or varieties where differences of similar magnitude may be expected as a more or less regular occurrence?

The Kansas experiments with Dole 90-Day corn give both the highest and the lowest yields for tip seed and the highest yield recorded for butt seed and the next to the lowest. Is Dole 90-Day corn a variety which fluctuates very much as to yield? Or is the Kansas climate with its wide range of temperature responsible for such variation?

It would seem that the figures in Table 2 and the observations of the various writers quoted are conclusive in showing that no one part of the ear is markedly inferior for seed. The kernels from both the tip and the butt appear more prolific than those from the middle of the ear, and the tip seed is better than the butt.

Atkinson (1901) says that many farmers plant the seed from the entire ear, as the plants from the tip and butt kernels do not bloom at the same time as those from the middle kernels, and by this means the period of pollination is prolonged, thereby insuring a more complete fertilization of the ovules. Atkinson, however, gives no indication that definite data had been collected to support this opinion.

Speer (1888) says that the silks from the tips of the ears are generally from two to five days later than those from the lower part of the ear, and in some cases have been observed to be as much as ten

days later. Speer also notes the fact that the silks last fertilized produce the smallest kernels.

Halsted (1912) thinks that the first silks to appear are from a midzone of the ear, from which point development proceeds both towards the tip and the butt. Gernert (1912) says:

"The statement by some writers that the silks from the base of the ear appear first, is true only in a broad sense, meaning the lower portion of the ear. Many poorly filled butts and bare tips are found on ears pollenated soon after the first silks appear."

He gives an illustration of an ear of pearl popcorn pollinated at two different stages in its development, of which he says:

"The variety to which the ear belongs is a white pop and in the forenoon of the day on which the first silks appeared on this shoot it was selfed. Eight days later the silks were observed to be long and green, and pollen from a plant in a variety with a yellowish endosperm was then applied. The phenomenon known as xenia brought out the difference between the selfed and the hybrid kernels, as is apparent in the figure. It is significant that the first silks to appear did not come from the extreme base of the ear but slightly above it (as is shown by the irregular band of white kernels). At the end of eight days the silks at the tip of this ear were not yet developed as is indicated by the bare cob at the tip of the ear in the figure."

Gernert adds, however, that the appearance of the silks from the cob is very non-uniform. Perfect ears have been obtained in some instances by pollination on the second day after the silks were visible, although in the case just quoted the silks from the tip of the ear had not emerged at the end of eight days. The order of the appearance of the silks seems to vary greatly with different varieties of corn.

If there is an absence of wind at flowering time, there is little doubt that the silks from the butts and tips would be oftener cross-pollinated than those from the middle of the ear, and hence yield more. If this is the true explanation there should be many instances when there is little or no difference in the yield from the middle and end seed, but there should also be instances when the end seed gives larger yields. The figures in Table 2 support the view that in cases where winds at pollination time insure cross-pollination for the silks from the middle of the ear, there would be no difference between the yield from the butts, tips and middles that could not be accounted for by chance, while on the other hand, when atmospheric conditions are good for self-pollination, the yields from the tips and butts would be greater than from the self-pollinated middle seed. In other words, the large deviations should be in favor of the end seed. Further, when the tip yields are significantly greater than those from the

middle seed, the butt yields should also be greater, whereas when tip yields are low (the table shows them never to be lower than can be accounted for by chance) the butt yields may or may not be correspondingly low. The figures do show just this.

Let us examine them with this in mind. The probable error for the individual experiment taken without regard to size of plot, is ± 8.8 for tips and ± 7.9 for butts. If we take a deviation from the yield of middle seed of at least four times the probable error as too great to be attributed to chance, we find in Table 2, that there are for the tips 3 such deviations above the mean, and for the butts, 4. In 3 of the 4 cases where the yield of the butts exceeds that of the middles by a significant amount the yield of the tips is also high. There is no deviation below the middles as large as four times the probable error, the lowest figures being 28 for butts and 25 for tips. Relative yield of tip and butt seed may also be influenced by the type of corn used, whether flint or dent.

Comparison of Flint and Dent Corn.

Table 4 is a rearrangement of the data exhibited in Table 2, and is designed to show the comparative behavior of flint and dent corn, regarding the relative yield from butt, middle and tip seed. It will be seen that with dent corn the yield of tip and butt seed respectively is 8 and 9 percent above the yield from seed from the middle of the ear, whereas with flint corn the yield from the butt seed is equal to that from the middles and the yield from the tip seed 4 percent greater than from the middles. Flint corn has been reported to show pollen and silk at the same time much oftener than dent corn does (Sturtevant 1883). Experiments may show further that the disparity in the time of appearance of silks from the middle and the ends of the ear is also a character that differentiates the flint from the dent varieties. It should also be kept in mind that the greater tendency of flint varieties to produce tillers extends the period during which pollen is being shed and reduces the chances of differential pollination. This table seems to support the observation made by Duggar (1896) and Georgeson, Burtis and Shelton (1891) that dent varieties yield most from butt seed whereas flint yields most from tip seed.

Germination.

The relative germination of butt, middle and tip seed was noted by Sturtevant (1883) in connection with his experiments as to relative yield. His data are given in Table 5.

TABLE 4. *Flint and Dent Corn Compared as to Relative Yield of Butt, Middle and Tip Seed.*

Flint Corn.					Dent Corn.				
Locality.	Year.	Relative Yields.			Locality.	Year.	Relative Yield.		
		Butt.	Middle.	Tip.			Butt.	Middle.	Tip.
Alabama...	1896	114	100	97	Alabama .	1896	99	100	97
	1897	101	100	112		1896	151	100	131
	1898	94	100	103		1896	101	100	90
New York..	1882	134	100	134	Arkansas.	1892	111	100	99
	1883	99	100	104	Georgia..	1900	100	100	104
	1883	96	100	104		1910	107	100	111
	1883	104	100	99	Kansas...	1891	102	100	84
	1883	99	100	100		1891	102	100	99
	1883	97	100	115		1891	127	100	131
	1883	104	100	102		1891	105	100	91
	1883	98	100	99		1891	98	100	94
	1883	93	100	105		1893	142	100	109
	1883	102	100	103		1893	118	100	116
	1883	109	100	101		1893	155	100	159
	1884	95	100	98		1893	84	100	221
	1884	107	100	109		1893	100	100	75
	1884	116	100	115		1895	112	100	96
	1884	95	100	106	Ohio.....	1886	120	100	111
	1884	99	100	103		1888	99	100	95
	1884	92	100	108		1889	100	100	101
	1884	95	100	84		1890	117	100	114
	1884	93	100	104		1891	99	100	95
	1884	107	100	120		1892	96	100	103
	1884	91	100	106		1893	96	100	98
	1884	105	100	107		1894	99	100	106
	1884	101	100	103		1895	98	100	101
	1884	101	100	93		1896	94	100	85
	1884	91	100	108					
	1884	96	100	95	Means...	....	109±2.04	100	108±2.81
	1884	99	100	98					
	1884	96	100	101					
	1884	100	100	102					
	1884	93	100	98					
	1884	95	100	100					
	1885	95	100	98					
Wisconsin..	1871	104	100	95					
	1873	94	100	96					
	1874	102	100	113					
Means.....	....	100±.80	100	104±.84					

TABLE 5. *Relative Germination of Butt, Middle and Tip Kernels.*

Type.	Variety.	Butt.	Middle.	Tip.
Flint.....	Waushakum.....	110	100	132
Dent.....	Minnesota.....	98	100	100
Do.....	Early.....	342	100	138
Do.....	Sibley's Pride of the North.....	100	100	97
Means...	.....	142±25	100	112±5

These experiments, although too few to have much weight, are interesting because of their general agreement with Table 2. Devol (1883) carries out some similar experiments and reports the results, but not in such a way as to enable us to tabulate them. He says that in 96 tests of the relative germination of the butt, tip and middle seed of corn, 70.3 percent of the tip seed germinated, 58.7 percent of the middle seed, and 76.3 percent of the butt seed. The following year there were 580 tests made, in which 76.1 percent of the tip seed, 74.2 percent of the middle seed, and 84 percent of the butt seed germinated. He goes on to state, but without any data to support the observation, that the radicle from the tip kernels is almost invariably weaker than from the butt or middle kernels. The root from the middle kernels sends out its root hairs sooner than the root of the butt kernels does. The butt kernels send out two lateral rootlets nearly as strong as the central root and almost simultaneously with it, while the lateral roots are weaker in the middle kernels and slower to start.

Sturtevant (1883) thinks that probably germinative and vegetative properties do not always correspond. The vitality of tip kernels is shown to be manifestly superior to that of the butt or middle kernels in flint corn, by the higher percentage of germination; the tip kernels of dent corn, however, did not show this superiority. Flint corn dries out more quickly than dent, which may account for its greater germinative ability. It has been suggested by the Ohio Agricultural Experiment Station in Newspaper Bulletin 170, 1897, that as the ends of the ear dry out more quickly than the middle portion, it may be that under some conditions the middle grains may be injured when the butts and tips escape.

Conclusions.

It would seem, if practical results are what is sought, that the experiments reported, covering a period of 45 years, are sufficient to decide the relative merits of butt, tip and middle kernels for seed. The experiments have been planned carefully, have been carried out in the various climates suited to corn growing, and ten different varieties of corn have been used.

The figures in Table 2 give the average yield of seed from the butt as 103 percent of that from the middle seed and the yield of seed from the tips as 105 percent of that from seed from the middle of the ear. In the case of the tips this is 5 times the probable error for the series, and in the case of the butts, 3⅓ times. These percentages, though small, must be considered significant in a table of 81 instances.

The higher figure for tips over butts may be explained by the fact that whereas occasionally the butt and middle silks appear almost simultaneously, the tip silks always appear last, and so are cross-fertilized more frequently than those from the butt of the ear. The yield from tip seed, therefore, often would be greater than that from the butt seed, in spite of the smaller size of the tip kernels.

In 4 out of the 81 cases reported we may be sure that the yield has been increased by the use of tip seed, and in the other cases there is no evidence that the use of tip seed has decreased the yield. In 4 cases the increased yield from butt seed is more than 4 times the probable error.

The conclusion of the matter seems to be that the tips and butts are certainly not inferior for seed purposes, and there seems little justification for the practice, prevalent in some sections, of discarding them for seed.

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THE EFFECT OF DIFFERENT METHODS OF INOCULATION ON THE YIELD AND PROTEIN CONTENT OF ALFALFA AND SWEET CLOVER.[1]

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Introduction.

The farm crops section of the Division of Agronomy and Farm Management of the Minnesota station has had in operation for a number of years a series of investigations of different methods of seeding alfalfa, with a view to ascertaining the best methods of securing a uniform stand of hardy strains adapted to Minnesota conditions. Among the problems which are being studied are: The date of seeding; the method of seeding; the use or omission of a nurse crop; various methods of inoculation, with and without liming; the use of different forms of lime; and tests of different strains of hardy varieties. Interspersed among the alfalfa plots are a considerable number of plots of white sweet clover which receive similar treatment.

In the several different series of these investigations, located in different fields and started in different years, there are duplicate plots which have received the same inoculation treatments at the time of seeding, with adjacent untreated check plots. Therefore, it appeared that these plots would afford excellent material for a comparative study of the effect of the different methods of inoculation, not only upon the yield of hay but also upon the chemical composition of the resultant crops. During the harvesting of the several cuttings from these plots in 1914, samples were taken for analysis. The results of the work show such consistent effects of the inoculation in the several different fields, at the different intervals after the year of seeding, that it is deemed desirable to publish them at the present time.

The study is to be continued. The data are presented as a report of progress, the results seeming to justify immediate publication. Since this is only a preliminary report for the purpose of presenting data for the interest and value which they may possess, and not a

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final review of the investigation, no attempt is made at this time to review the literature on the subject.

I. The Effect of Different Methods of Inoculation on the Yield and Composition of the Hay Crop.

First Series, Fields E and F; Commercial Culture versus Inoculation with Soil, with and without Liming.—The seedings in Field *E* on the University Farm were made during the spring and summer of 1912. The series on which the alfalfa was sown had been heavily manured and cropped to mangels in 1910 and 1911. At the time the alfalfa was seeded, the soil on these plots was above the average in productivity, because of the heavy manuring which it had received. Further, just across a 16-foot roadway from these plots, there was a series in which alfalfa had been growing thriftily for six years. The 19 plots of this series (1/20 acre each) included comparisons of drill *vs.* broadcast seeding; barley as a nurse crop *vs.* no nurse crop; seeding at varying rates per acre and at different dates; inoculation with commercial culture on seed and on soil; and inoculation by soil transfer, with and without liming, *vs.* no inoculation. The inoculation by soil transfer in all these investigations was made by applying soil from a field in which the particular legume had been growing for some years to the plot at the rate of 200 pounds per acre and harrowing immediately. From the start the alfalfa on all the plots in Field *E* was thrifty and dark green in color. Examination showed some nodules on the roots of plants in the uninoculated plots, undoubtedly because of the close proximity of alfalfa in the adjoining series, and a great abundance on the plants in the inoculated plots. Under such conditions the inoculation might be expected to show minimum effects.

The soil in Field *F*, on the other hand, is in a state of only medium productivity. Alfalfa has never been grown nearer than 30 rods from the plots used in these experiments. These plots (1/40 acre each), 68 in number, were seeded in the spring of 1913. The series included duplicate plots for each of the following comparisons: Tests of strains of Grimm alfalfa from Minnesota and Montana and of commercial stocks of Grimm and Turkestan, of ordinary alfalfa from Kansas and Nebraska, and of white sweet clover; drill *vs.* broadcast seeding; rye, barley, oats, wheat, and flax as a nurse crop *vs.* no nurse crop; and the same series of inoculation studies as those in Field *E*. The data showing the results of these different methods of seeding, covering the crops harvested over a series of years, will be

presented in another publication. The present paper deals only with the crops harvested in 1914 from the plots on which methods of applying inoculating material were compared. On Field *F* the alfalfa plants on the plots to which no inoculating material was supplied showed distinct lack of inoculation in 1914 at the time the first and second cuttings were made. Later in the season some plants in the uninoculated plots were found to have nodules on their roots.

As will be noted, there are 3 plots of each treatment, 2 in Field *F* and 1 in Field *E*. The 3 cuttings of the plots in Field *E* were made on June 10, July 20, and September 9, respectively. Those in Field *F* were made on June 18, July 26, and September 9. Each cutting was cured in cocks and protected against rain by canvas covers. When thoroughly field cured, the hay from each plot was weighed and a representative sample taken to the laboratory for determinations of dry matter and protein content. The yields, calculated to the basis of pounds per acre, are shown in Table 1.

TABLE 1.—*Effect of Different Methods of Inoculation of Alfalfa on Yield of Dry Matter per Acre.*

Method of Inoculation.	Plot No.	First Cutting.			Second Cutting.			Third Cutting.			Total Yield Dry Matter.
		Cured Hay.	Moisture.	Dry Matter.	Cured Hay.	Moisture.	Dry Matter.	Cured Hay.	Moisture.	Dry Matter.	
		Lbs.	*%*	*Lbs.*	*Lbs.*	*%*	*Lbs.*	*Lbs.*	*%*	*Lbs.*	*Lbs.*
None	11	3,783	18.9	3,068	3,492	23.0	2,689	2,589	22.3	2,011	7,768
	18, 52	3,000	28.5	2,142	3,260	13.0	2,839	2,700	20.7	2,150	7,131
	Ave.	.....	.....	2,450	.....	.....	2,789	.....	.....	2,104	7,343
Commercial culture applied to seed	12	4,132	14.3	3,541	3,783	22.8	2,920	2,534	19.1	2,050	8,511
	24, 58	3,020	23.4	2,308	3,320	11.7	2,969	2,560	23.6	2,092	7,369
	Ave.	.....	.....	2,719	.....	.....	2,953	.....	.....	2,078	7,750
Commercial culture applied to soil	13	3,928	17.4	3,244	3,579	27.8	2,584	2,502	19.5	2,014	7,842
	25, 59	3,220	28.6	2,287	3,460	10.7	3,090	2,580	22.4	2,002	7,379
	Ave.	.....	.....	2,606	.....	.....	2,921	.....	.....	2,006	7,533
Soil from alfalfa field	14	4,365	15.9	3,671	3,637	23.4	2,786	2,473	24.3	1,872	8,329
	26, 60	3,760	25.6	2,804	3,520	14.5	3,005	2,500	20.5	1,980	7,789
	Ave.	.....	.....	3,093	.....	.....	2,932	.....	.....	1,944	7,969
Soil from alfalfa field + 2 tons limestone per acre	15	4,452	22.0	3,472	3,404	26.0	2,519	2,269	24.0	1,724	7,715
	27, 61	3,840	29.9	2,668	3,620	8.1	3,331	2,680	21.8	2,096	8,095
	Ave.	.....	.....	2,936	.....	.....	3,061	.....	.....	1,972	7,969
None + 2 tons limestone per acre	16	4,568	14.6	3,901	3,317	25.0	2,487	2,534	23.8	1,931	8,319
	28, 62	3,280	29.2	2,320	3,620	6.2	3,396	2,660	23.9	2,025	7,741
	Ave.	.....	.....	2,847	.....	.....	3,093	.....	.....	1,994	7,934

These results show a slight increase in yield in the second and third years after seeding due to the inoculation with commercial cul-

ture (the inoculation applied to the seed being apparently more effective than that applied to the soil), and a quite significant increase from the inoculation with soil from an old alfalfa field. Liming (2,000 lbs. ground limestone per acre) at seeding time, without inoculation, appears to be almost as efficient on these lands as inoculation. The series on the Quinn Farm, outlined below, show a much more pronounced effect of the inoculation in increasing the yield of the hay crops the first year (second year after seeding) than is here indicated. It is interesting to note, however, that a consistent beneficial effect was found on the 3 separate plots in these series on both heavily manured land and soil of medium productivity, extending into the third year after seeding.

It will be observed that, as might be expected, there are occasional variations from the general rule in the case of individual cuttings from particular plots; but the next following cutting almost invariably gave correspondingly larger or smaller yields, so as to balance up the total yield for the season. Apparently these fluctuations are due to some local disturbing influence which prevents the crop from utilizing normally the plant food supply in the soil, and the next following cutting profits or loses by the draught on the soil during the growth made by the preceding cutting.

The results of the determinations of the percentage of protein[2] in the samples from each of the cuttings on each of these plots are shown in Table 2.

These results show a surprisingly consistent effect of the inoculation at seeding time upon the percentage of protein in the crops cut two years later in Field *E* and one year later in Field *F* from the different plots. As in the case of yields of dry matter per acre, there are occasional fluctuations, but these are almost invariably followed by a corresponding reversal of relationships in the next succeeding cutting. As the determinations of nitrogen upon which these calculations were based were made by laboratory assistants who had no information as to the origin of the samples, or purpose of the investigations, the consistency of the results is explainable only on the basis of an actual effect of the inoculation in 1912 upon the chemical composition of the crop in 1914.

[2] In all the discussions in this paper, the term protein is used to designate what is commonly called "crude protein," i. e., nitrogen × 6.25. All determinations were made in duplicate, and the results presented are the average of closely agreeing duplicates, in every case.

TABLE 2.—*Effect of Different Methods of Inoculation on the Protein Content of Alfalfa.*

(Field E, Series I, Plots 11–16; Field F, Series III, Plots 18–62.)

Kind of Inoculation.	Plot No.	Percentage of Protein in the Dry Matter.			
		First Cutting.	Second Cutting.	Third Cutting.	Average.
None	11	17.58	16.52	18.50	17.53
	18	15.46	14.83	16.48	15.59
	52	14.40	14.30	18.95	15.88
	Ave.	15.81	15.22	17.98	*16.34*
Commercial culture applied to seed	12	14.87	15.80	17.98	16.22
	24	14.54	16.25	19.57	16.77
	58	14.50	14.49	19.64	16.21
	Ave.	14.64	15.51	19.06	*16.40*
Commercial culture applied to soil	13	17.94	16.08	19.83	17.95
	25	15.35	15.37	17.43	16.05
	59	16.25	14.88	19.57	16.90
	Ave.	16.51	15.45	18.94	*16.97*
Soil from alfalfa field	14	18.53	15.03	18.41	17.32
	26	15.49	14.98	19.64	16.70
	60	15.99	14.70	20.21	16.97
	Ave.	16.67	14.90	19.42	*17.00*
Soil from alfalfa field + 2 tons limestone per acre	15	19.25	15.19	20.58	18.34
	27	16.94	16.08	19.48	17.50
	61	17.63	15.83	21.17	18.21
	Ave.	17.94	15.70	20.41	*18.02*
None + 2 tons limestone per acre	16	17.56	15.99	19.01	17.52
	28	17.17	16.26	18.25	17.23
	62	14.71	12.07	19.06	15.28
	Ave.	16.48	14.78	18.74	*16.67*

Second Series, Quinn Farm, Inoculation of Alfalfa by Transfer of Soil from Sweet Clover and Alfalfa Fields, with and without Liming.—The soil in this series has received no manure for many years. It is low in productivity as compared with the soils on Fields *E* and *F*. No alfalfa had been grown within half a mile of the field. Twenty-three duplicate plots of 1/16-acre each were seeded, one of each pair with alfalfa and the other with sweet clover. Every other plot in each set is an untreated check plot, and the treated plots are so arranged that in each set there are 11 check plots. At seeding time there was applied to 3 plots 200 pounds per acre of soil from an old alfalfa field. Similar applications of soil were made to 3 other plots, and in addition 2,000 pounds per acre of ground limestone were applied. There were also 3 plots to which 200 pounds per acre of soil from an old sweet clover field were applied, and 3 plots to which

sweet clover soil and limestone were added. The alfalfa and sweet clover were sown in April, 1913, with 2 bushels of oats per acre as a nurse crop. The alfalfa was Turkestan, and the sweet clover, the white-flowered strain. The results reported, therefore, are for the first crop, taken in the second season from the time of seeding.

Observation of the series of plots early in the season showed some lack of uniformity in the growth on the different check plots. Near the center of the series a group of adjacent plots was found on which the growth on the check plots was fairly uniform in appearance and quantity. Five plots, including 3 check plots and 1 each which had been inoculated with soil from an old alfalfa field and from an old sweet clover field respectively, were selected for the purposes of this investigation. All of these plots except the checks were limed at seeding time with 2,000 pounds ground limestone per acre. The plots were harvested and sampled as described for the preceding series. The alfalfa was cut on June 22, July 27, and September 12. The single cutting of sweet clover was made on June 22.

The yields per acre of cured alfalfa hay and of dry matter secured from these plots are shown in Table 3. The yields of dry matter from the sweet clover plots are included with the results of the analyses of the samples of hay in Table 7, in order to save repetition in tabulation.

TABLE 3.—*Effect of Inoculation of Alfalfa with Soil from Sweet Clover Field and from Alfalfa Field on Yield of Dry Matter Per Acre.*

Plot No.	Kind of Inoculation.	First Cutting.			Second Cutting.			Third Cutting.			Total Yield Dry Matter.
		Cured Hay.	Moisture.	Dry Matter.	Cured Hay.	Moisture.	Dry Matter.	Cured Hay.	Moisture.	Dry Matter.	
		Lbs.	%	*Lbs.*	*Lbs.*	%	*Lbs.*	*Lbs*	%	*Lbs*	*Lbs.*
12	None	598	12.9	521	573	5.8	549	264	18.0	216	1,277
13	With sweet clover soil	1,518	17.2	1,258	1,320	11.8	1,164	766	20.8	606	3,028
14	None	523	16.3	438	921	10.6	822	509	16.8	423	1,683
17	With alfalfa soil	1,245	22.1	980	1,518	13.2	1,317	977	25.9	725	3,022
20	None	423	19.7	340	722	10.5	646	370	17.3	307	1,293

The results show a regular and very large increase in yield of alfalfa in the second year after seeding as a result of inoculation. They show also that inoculation with soil on which sweet clover has been grown is equally efficient with that on which alfalfa has been grown in producing this result. The same effect upon the growth of the sweet clover is shown in Table 7 (which see).

The results of the determinations of protein in the hay from these plots are shown in Table 4.

TABLE 4.—*Effect of Inoculation on Protein Content of Alfalfa.* (*Quinn Farm.*)

Plot No.	Kind of Inoculation.	Percentage of Protein in the Dry Matter.			
		First Cutting.	Second Cutting.	Third Cutting.	Average.
12	None	11.99	12.35	13.45	12.60
13	With sweet clover soil	18.53	13.87	14.96	15.79
14	None	14.94	12.20	11.67	12.60
17	With alfalfa soil	17.81	13.48	15.46	15.55
20	None	12.02	10.03	16.18	12.73

Here, again, a very marked influence of the inoculation is shown. The percentage of protein in the dry matter from the inoculated plots was uniformly considerably higher than in that from the uninoculated ones. As in the first series, an occasional variation appears, which is accompanied by a corresponding change in composition in the following cutting from the same plot.

It appears from the data shown in Tables 3 and 4 that on the soil of central Minnesota, as represented by these three fields of soil of varying productivity on the University Farm, a very significant increase in both the yield and protein content of alfalfa in the second year after seeding results from applying at seeding time soil on which either inoculated alfalfa or white sweet clover plants formerly have been grown. That this effect extends over into the next succeeding year, but in a diminished degree, is indicated by the data presented in Tables 1 and 2.

At the same time that the analyses of the above-described samples were being made, there was sent in to the laboratory a series of samples of the first cuttings from plots of alfalfa grown on the demonstration farm at Monticello, Minn., on which a series of comparative inoculations precisely similar to those on the plots in Fields *E* and *F* on the University Farm had been made. In this series, duplicate plots seeded in the spring of 1913 were given the treatment with commercial culture on seed, with alfalfa soil, with alfalfa soil plus lime, with lime alone, and check plots left untreated, using the same quantities per acre as on the plots on University Farm. The samples represented the first cutting taken from these plots in the second year after seeding. The percentage of dry matter in these samples and of protein contained in it was determined. The results are shown in Table 5.

TABLE 5.—*Effect of Inoculation on Protein Content of Alfalfa.*
(Field N, Monticello, Minn.)

Kind of Inoculation.	Percentage of Protein in the Dry Matter.				
	Plot No.	Percent.	Plot No.	Percent.	Average.
Alfalfa soil + lime	1	23.07	6	23.46	23.26
Alfalfa soil	2	24.75	7	24.17	24.46
None	3	18.16	8	17.30	17.73
Commercial culture	4	20.46	9	21.70	21.08
None + lime	5	25.18[3]	10	21.65	21.65

The same effect of the different treatments upon the percentage of protein in the dry matter as was found in the other series appears in these results. The actual quantitative effect is different, as might be expected from the different soil and environmental conditions under which the crop was grown, but the same general effect is to be observed.

It appears from all the data presented above that both the yield of dry matter per acre and the percentage of protein contained in it are increased by the several treatments. Both of these effects would, of course, increase the total yield of protein per acre. The actual amount of this increase for each of the several different treatments and in the different years of growth represented by the 3 different series on the University Farm is shown in Table 6.

TABLE 6.—*Effect of Different Methods of Inoculation of Alfalfa on Total Yield of Protein Per Acre.*

Kind of Inoculation.	No. of Plots.	No. of Cuttings.	Average Yield per Acre.	
			Dry Matter.	Protein.
FIELD E, SERIES I, AND FIELD F, SERIES III			*Lbs.*	*Lbs.*
None	3	3	7,343	1,191
Seed inoculated with commercial culture	3	3	7,750	1,241
Soil inoculated with commercial culture	3	3	7,533	1,239
Soil inoculated with alfalfa soil	3	3	7,969	1,335
Soil inoculated with alfalfa soil + 2 tons limestone per acre	3	3	7,969	1,406
None + 2 tons limestone per acre	3	3	7,934	1,281
QUINN FARM				
None	1	3	1,277	159
Soil from alfalfa field	1	3	3,028	485
None	1	3	1,683	215
Soil from sweet clover field	1	3	3,022	472
None	1	3	1,293	155

[3] Omitted from average, sample badly discolored and showing signs of fermentation.

Effect of Inoculation of Sweet Clover with Soil from Alfalfa and from Sweet Clover Fields.—The treatments and methods of harvesting and sampling of the plots of sweet clover on the Quinn Farm have been described above. The single cutting of hay which the plots afforded was made on June 22. The yields of cured hay and of dry matter per acre, the percentages of protein in the dry matter, and the yields of protein per acre from these plots are shown in Table 7.

TABLE 7.—*Effect of Different Methods of Inoculation of Sweet Clover on Yield and Protein Content of the Crop.*

Plot No.	Kind of Inoculation.	Yield.			Protein Content.	
		Cured Hay per Acre.	Moisture.	Dry Matter per Acre.	In Dry Matter.	Total per Acre.
		Lbs.	*Percent.*	*Lbs.*	*Percent.*	*Lbs.*
12	None	240	46.7	128	17.04	22
13	With sweet clover soil	1,664	27.4	1,208	15.76	190
14	None	240	37.2	151	15.93	24
17	With alfalfa soil	2,048	48.9	1,046	14.76	154

The results in Table 7 show a very marked effect of the inoculation upon the growth of sweet clover. The yield of dry matter was enormously increased, while the percentage of protein in the dry matter, contrary to the results with alfalfa, was decreased by inoculation with either alfalfa soil or sweet clover soil. Other plots of the series which had received these same treatments showed similar effects upon the yield of hay, but the check plots in these other portions of the series were so irregular in their growth and yield that the results were inconclusive. The data presented in Table 7 are insufficient to permit definite conclusions, but since they are confirmed by the additional data presented in Part II of this paper, they are deemed worthy of consideration and are therefore presented at this time.

II. The Effect of Inoculation on Yield and Composition of Tops and Roots of Alfalfa and Sweet Clover.

In order to ascertain the effect which the application of soil containing the proper bacteria at seeding time has upon the actual development of individual plants, the following procedure was undertaken. Among the plots on the Quinn Farm in which both alfalfa soil and sweet clover soil had been used for inoculation of each of these crops, adjacent plots were selected on one of which soil had been supplied at seeding time with its own particular type of bacteria and the other left as an untreated check plot. On each of these 4

plots, 3 separate areas of exactly 1 square yard were measured at different places in each plot where the stand of plants appeared uniform and of about the average thickness for the entire plot. In each of these 12 square-yard tracts, the whole number of plants was carefully washed and dug out, so as to secure as completely as possible the entire top and root growth of all the plants. The total number of plants from each tract was counted and the tops and roots cut apart and bagged separately. These samples, consisting in each case of the entire growth of tops or roots from a single square-yard tract,

TABLE 8.—*Effect of Inoculation on Growth of Tops and Roots of Sweet Clover and of Alfalfa.*

SWEET CLOVER.

Plot No.	Treatment.	Sq.Yd. No.	No. of Plants.	Part of Plants.	Green Weight.	Total Dry Matter.	Dry Matter per Plant. Tops and Roots.	Dry Matter per Plant. Total.	Dry Matter per Plant. Average, for Plot.
					Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
13	Inoculated.....	1	70	Tops	2,128	362.9	5.184	6.410	7.148
				Roots	422	85.8	1.226		
		2	91	Tops	3,150	519.8	5.712	7.356	
				Roots	791	149.6	1.644		
		3	60	Tops	1,948	324.0	5.400	6.678	
				Roots	409	76.7	1.278		
12	Not inoculated..	4	113	Tops	358	64.1	0.567	0.771	0.694
				Roots	88	23.1	0.204		
		5	32	Tops	136	18.5	0.578	0.767	
				Roots	30	6.7	0.209		
		6	37	Tops	96	14.5	0.393	0.544	
				Roots	30	5.5	0.151		

ALFALFA.

17	Inoculated.....	7	178	Tops	1,590	357.7	2.010	3.006	2.344
				Roots	655	177.3	0.996		
		8	256	Tops	1,690	360.5	1.409	2.029	
				Roots	549	158.8	0.620		
		9	180	Tops	1,286	263.7	1.465	2.098	
				Roots	407	114.0	0.633		
20	Not inoculated..	10	119	Tops	138	32.4	0.272	0.464	0.572
				Roots	59	22.8	0.192		
		11	181	Tops	233	54.2	0.299	0.494	
				Roots	104	35.2	0.195		
		12	133	Tops	246	64.0	0.482	0.758	
				Roots	99	36.7	0.276		

SUMMARY.

Gain in dry matter per plant due to inoculation, alfalfa	310
Gain in dry matter per plant due to inoculation, sweet clover	928
Gain in dry matter per square yard due to inoculation, alfalfa	484
Gain in dry matter per square yard due to inoculation, sweet clover	1,046

were sent to the laboratory for determinations of green weight and percentage of dry matter. The number of plants from each of the tracts, the total weight of green material in the tops and in the roots, and the corresponding weight of dry matter per square yard and per plant, are shown in Table 8.

The data in Table 8 show, as was to be expected from the total yields from the plots from which these sample square-yard tracts were taken, a large gain in both tops and roots in quantity of dry matter produced in the second year of growth as a result of the inoculation at seeding time. They show further that the gain in weight was an actual increase in dry matter per plant and not an increase in the number of plants growing upon the given area of soil. During the course of the tabulation of these data, it became apparent that the increase due to the inoculation was greater in the case of the tops than in the roots of the plants, or, in other words, that there was a greater proportion of tops to roots in the plants from the inoculated plots than in those from the untreated check plots. As soon as this became apparent, the actual ratio of dry weight of tops to dry weight of roots in each of the 12 samples was calculated, with the results shown in Table 9.

TABLE 9.—*Effect of Inoculation on Ratio of Top to Roots in Sweet Clover and Alfalfa.*

Sq. Yd. No.	Crop.	Treatment.	Ratio of Dry Matter in Tops to Roots.	Average for Plot.	
				Plot No.	Ratio.
1	Sweet clover....	Inoculated.....	4.23 : 1		
2	Sweet clover....	Inoculated.....	3.48 : 1	13	3.98 : 1
3	Sweet clover....	Inoculated.....	4.23 : 1		
4	Sweet clover....	Not inoculated.....	2.78 : 1		
5	Sweet clover....	Not inoculated.....	2.77 : 1	12	2.72 : 1
6	Sweet clover....	Not inoculated.....	2.61 : 1		
7	Alfalfa.....	Inoculated.....	2.02 : 1		
8	Alfalfa.....	Inoculated.....	2.27 : 1	17	2.20 : 1
9	Alfalfa.....	Inoculated.....	2.31 : 1		
10	Alfalfa.....	Not inoculated.....	1.42 : 1		
11	Alfalfa.....	Not inoculated.....	1.53 : 1	20	1.56 : 1
12	Alfalfa.....	Not inoculated.....	1.74 : 1		

Table 9 shows that in each individual case, with both the alfalfa and the sweet clover, the ratio of tops to roots was greater in the inoculated plot than in the untreated check plot. From this it appears that the beneficial effect of the inoculation upon the yield of hay is due not only to an increase in the total dry matter elaborated by each individual plant (as shown in Table 8), but also to the deposition of

a greater proportion of the material manufactured in the above-ground portion of the plants.

The above-mentioned facts made it desirable to determine, if possible, whether the inoculated plants were actually making more efficient use of the plant food constituents which they were obtaining, in the manufacture of dry matter, or whether they were simply able to make larger draughts on the soil because of the increased vigor of growth induced by the inoculation. Accordingly, determinations were

TABLE 10.—*Effect of Inoculation on Plant Food Constituents in Tops and Roots of Sweet Clover and Alfalfa.*

Plot No.	Crop.	Treatment.	Sq. Yd. No.	Part of Plant.	Plant Food Constituents (Calculated as Percentages of the Dry Matter).			
					Ash.	Nitrogen.	P_2O_5.	K_2O.
13	Sweet clover.	Inoculated.....	1	Tops	6.01	2.28		
			2	Tops	6.90	2.63	1.28	0.741
			3	Tops	7.04	2.61		
12	Sweet clover.	Not inoculated ..	4	Tops	12.29	2.36		
			5	Tops	11.70	3.04	1.23	1.200
			6	Tops	10.78	3.42		
13	Sweet clover.	Inoculated.....	1	Roots	15.00	1.30		
			2	Roots	12.29	1.50	1.13	0.435
			3	Roots	14.57	1.33		
12	Sweet clover.	Not inoculated ..	4	Roots	7.63	1.03		
			5	Roots	7.05	1.22	1.16	0.950
			6	Roots	6.64	1.34		
17	Alfalfa.....	Inocu ated.....	7	Tops	9.39	2.57		
			8	Tops	9.56	2.52	1.02	0.999
			9	Tops	8.13	2.46		
20	Alfalfa.....	Not inoculated ..	10	Tops	12.38	2.09		
			11	Tops	13.40	2.01	1.34	1.110
			12	Tops	13.37	1.91		
17	Alfalfa.....	Inoculated.....	7	Roots	6.04	1.74		
			8	Roots	8.00	1.72	1.33	0.730
			9	Roots	7.01	2.10		
20	Alfalfa.....	Not inoculated ..	10	Roots	6.88	1.32		
			11	Roots	8.86	0.88	1.14	0.640
			12	Roots	7.63	0.88		

made of the percentage of total ash and of nitrogen, phosphorus and potassium in the dry matter in these samples. For the determinations of total ash and nitrogen the individual square-yard samples were used, while for those of phosphorus and potassium, composites containing equal quantities of material from each of 3 square-yard samples of

the same plot were used. The results of these determinations, calculated as percentage of the dry matter and expressed in the terms commonly used in reporting analyses of this kind, are shown in Table 10.

The figures for total ash in the dry matter in Table 10 show a very remarkable effect of the inoculation in increasing the ash content of the roots and decreasing it in the tops of the plants. This effect is apparently in other constituents than the phosphorus and potassium, however, as the percentage of phosphorus (expressed as P_2O_5) in the dry matter is not significantly affected by the inoculation, while that of potassium (expressed as K_2O) is higher in the uninoculated plants, in both roots and tops, except in the case of the alfalfa roots. It appears that some other elements than those which were determined in this work are responsible for the wide fluctuations in ash content of the inoculated plants as compared with uninoculated ones. It seems probable that calcium and perhaps magnesium may be largely concerned in this matter, and it is proposed to make a careful study of this matter during the coming season. Lack of material (particularly from the uninoculated plots) prevented further analytical work on the samples used in the above described work. The nitrogen content, since these are leguminous plants and hence when inoculated draw a considerable proportion of their nitrogen from the air by the aid of the symbiotic bacteria rather than from the soil, would not be expected to vary in the same direction or proportion as the other plant food elements. It is important to note, however, that although the roots of the inoculated plants do not show a decided increase in percentage of nitrogen, the much larger weight of dry matter produced by these plants leaves in the soil, as a residue, much more organic matter and nitrogen than is left by the roots in the uninoculated plots. The value of inoculation from the standpoint of effect upon subsequent nitrogen supply in the soil, even on soils in as good productive condition as these, is clearly demonstrated.

The same effects of inoculation that were observed in the samples from the various cuttings from the large plots, namely, an increase in percentage of protein (or nitrogen) in the dry matter of alfalfa and a decrease in that in the sweet clover as a result of the inoculation at seeding time, are shown in these analyses, the only exception being that the root portions of the sweet clover were not significantly affected in either direction by the inoculation.

Finally, the calculated quantities of these constituents present in the several samples, expressed as pounds per acre, are shown in Table 11.

TABLE 11.—*Effect of Inoculation upon Quantity of Plant Food Constituents in Crops of Sweet Clover and Alfalfa.*

(Average of three square-yard plots in each case.)

Crop.	Treatment.	Part of Plants.	Plant Food Constituents Present in Crop.					
			Grams per Square Yard.			Pounds per Acre.		
			Nitrogen.	P_2O_5.	K_2O.	Nitrogen.	P_2O_5.	K_2O.
Sweet clover.	Inoculated....	Tops.....	10.05	5.15	2.98			
		Roots.....	1.46	1.17	0.45			
		Whole plant.	11.51	6.32	3.43	128	70	38
Sweet clover.	Not inoculated	Tops.....	0.86	0.40	0.39			
		Roots.....	0.13	0.14	0.11			
		Whole plant.	0.99	0.54	0.50	11	6	5
Alfalfa.....	Inoculated....	Tops.....	8.25	3.34	3.27			
		Roots.....	2.73	2.03	1.10			
		Whole plant.	10.98	5.37	4.37	122	60	49
Alfalfa.....	Not inoculated	Tops.....	0.99	0.67	0.56			
		Roots.....	0.31	0.36	0.20			
		Whole plant.	1.30	1.03	0.78	14	11	9

The data presented in Tables 10 and 11 appear to indicate that the large increases in dry matter per plant caused by the inoculation are due chiefly to the increased vigor of growth and power to absorb and utilize plant food constituents from the soil, rather than to utilize similar amounts of these elements for the production of increased dry matter by the plant. This is true at least so far as phosphorus and potassium are concerned. The data with reference to total ash might indicate some effect in ability to produce much larger proportions of dry matter from a given supply of mineral material as a result of the inoculation, but the study is not yet sufficiently complete in this direction to permit any conclusions to be drawn from it. We hope to add to the data on this point during the coming season.

The thanks of the authors are due to Miss Cornelia Kennedy and Mr. Morris J. Blish for most of the determinations of nitrogen from which the data concerning the protein content of these samples were computed.

VARIETAL NAMES OF OATS.[1]

W. C. ETHERIDGE,

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In connection with the discussion of varietal names of field crops in the January–February issue of the JOURNAL OF AGRONOMY,[2] the writer wishes particularly to point out the confusion in nomenclature and in forms of oat varieties grown in this country. In attempting a classification of oat varieties on a morphological basis it has been found that varietal names very often have little or no significance. Many different names are applied to the same variety and many different varietal forms are found under the same name. For example, let us consider the vagaries in nomenclature of the widely known variety, Swedish Select.

The Swedish Select oat was introduced into this country from the St. Petersburg province of Russia in 1898, by the U. S. Department of Agriculture. It had been carried to Finland and Russia from Sweden and was thought to be an improved strain, hence the name "Swedish Select." The distinct worth of the variety under the new conditions of this country was soon recognized. At the present time it is one of the most popular varieties among northern white oats, which perhaps accounts for the multiplicity of wrong names applied to it. No description of the Swedish Select was published at the time of its introduction beyond the statement that it was a "very large-grained, white oat."[3] The following description of the variety as it now exists in this country is therefore given, in order to delineate the type to which reference is here made.

Swedish Select.—Culms erect from early growth, medium large, stiff, glabrous; sheaths dark green with grayish bloom at period of full heading, scarcely covering the internodes; leaves colored as sheaths, medium wide, margins smooth; ligules well developed; rachis straight; panicles equilateral, medium long, somewhat compact, erect, the branches ascending; 3-grained spikelets usually numerous per panicle, sometimes predominating over 2-grained spikelets,

[1] Received for publication April 19, 1915.

[2] Montgomery, E. G., On Naming Varieties, JOUR. AMER. SOC. AGRON., 7: 29–31.

[3] Carleton, Mark Alfred, Russian Cereals, U. S. Dept. Agr., Div. Bot. Bul. No. 23, p. 21. 1900.

1-grained spikelets not occurring; glumes dark green with grayish bloom at period of full heading, usually 9-nerved, sometimes 10-nerved; grains white, plump, large, the outer grains short-pointed and on their dorsal side very concave at about the region of the awn; lemma smooth, 7-nerved; awn usually present, somewhat twisted but seldom geniculate, black at base; basal hairs absent or seldom occurring, if present few, weak and short; rachilla 2–3 mm. long, usually furrowed, nearly always glabrous. Plants medium in maturing, 80–90 days.

The material from which this description was drawn is included among about 700 so-called varieties and duplicates collected for classification from 40 experiment stations and 53 seedsmen. Among 36 lots bearing the name "Swedish Select," from 22 stations and 8 seedsmen, only 23 are alike; and these constitute the variety here described. Of the 22 stations 6 were growing varieties other than Swedish Select under that name. Of the 8 seedsmen 2 were selling other varieties under the name "Swedish Select." In a few cases several widely different forms had been grown as Swedish Select by the same station. Among 13 lots which did not conform to the type, the forms ranged from varieties closely resembling Swedish Select to side panicle oats and, in one case, to Red Rustproof.

On the other hand, the Swedish Select form occurred among the 700 lots under 93 different names and variations of names, while most of these names were in turn applied to other different forms. Frequently the misnomers were "pedigreed" or "selected" numbers of various experiment stations. In other cases, such popular names as National, Lincoln, Roosevelt, President, Banner, Twentieth Century, Golden Fleece, and Prosperity were applied to the Swedish Select and to other different forms as well.

The confusion in nomenclature and in forms is, however, by no means confined to Swedish Select, which is cited here merely to illustrate a fault which is all too common. In fact nearly all forms are frequently misnamed and nearly all names are applied to different forms. Clearly, then, varietal names for oats are to a great extent meaningless and there is no uniform conception of type among experiment station investigators or seedsmen.

The editorial suggestion in the January–February JOURNAL as to the difficulty in correlating results of varietal tests is particularly applicable to tests of oat varieties. In the present confusion of names and forms, a list of varietal names is of little use for indicating the actual varietal forms in the list. A single form under various names may comprise a large part of the list; perhaps several forms are misnamed; and in either case the results of the test must be mis-

leading. It therefore follows that results of many varietal tests are actually harmful, for the reason that conclusions from such results often place an undue valuation upon an unworthy name or debase the name of a high yielding variety by applying it to a worthless form. This doubtless has been a large factor in causing the lack of uniformity in results of varietal tests. Many failures of varieties charged to their lack of adaptation often could be better explained, perhaps, by the fact that the variety in question was present in name only.

The ultimate practical end of varietal tests, of course, is to provide the farmer with accurate information as to the yielding power of varieties; but wherein lies the propriety of tacitly recommending varieties by the publication of names which may or may not refer to the particular forms which have yielded well in a given test? What assurance is there that farmers, acting on our recommendation, may not receive from seedsmen a worthless variety under the name which we have recommended? The latter circumstance need not result necessarily from dishonesty on the part of the seedsman, but rather from his ignorance of types.

There seems to be no better plan for setting right the confusion in the nomenclature of crop varieties than that suggested by Professor Montgomery, namely, the establishment of an official register for these varieties. If varieties now extant could be described accurately, named officially and registered, we should have not only an invaluable reference for the identification of forms, but also an elimination of the vast confusion of meaningless varietal names. This would be the basis for better and more serviceable work in agronomy. With the common use of standard types, officially named, we should be able to reach definite conclusions regarding the performance of a given variety under various conditions. Furthermore, if seedsmen were required to register their varieties and permitted to sell them only under official names, we might then feel that our recommendations of varieties would be justified by practical results.

AGRONOMIC AFFAIRS.

PROGRAM FOR THE BERKELEY MEETING.

A tentative program for the meeting of the American Society of Agronomy on the campus of the University of California, Berkeley, has been arranged from the titles of papers which have been submitted to the Secretary. As this is written nearly two months before the meeting, it is probable that several additional papers will be available, titles of which have not yet been presented. Shifting of papers to suit the individual convenience of those presenting them can be arranged without difficulty. The program as now planned is as follows:

Monday Afternoon, August 9.

1. The Progressive Development of the Wheat Kernel, Dr. R. W. Thatcher, Experiment Station, St. Paul, Minn.

2. Smut Explosions and Fires Occurring during Thrashing in the Wheat Fields in Eastern Washington, Prof. E. G. Schafer, Experiment Station, Pullman, Wash.

3. Formation and Classification of the Soils of Arid Regions, Prof. Chas. F. Shaw, University of California, Berkeley, Cal.

4. Climatic Effects on Oats, Prof. Alfred Atkinson, Experiment Station, Bozeman, Mont.

Monday Evening, August 9.

Joint Session with the Society for the Promotion of Agricultural Science and the American Farm-Management Association.

1. Presidential Address for the Society for the Promotion of Agricultural Science, Dr. H. J. Waters, Kansas State Agricultural College, Manhattan, Kans.

2. Presidential Address for the American Society of Agronomy, Dr. C. E. Thorne, Ohio Agricultural Experiment Station, Wooster, Ohio.

3. Presidential Address for the American Farm-Management Association, Prof. Andrew Boss, College of Agriculture, St. Paul, Minn.

Tuesday Morning, August 10.

1. Breeding Early and Late Strains of Manchuria Barley, Prof. C. P. Bull, Experiment Station, St. Paul, Minn.

2. A Critique of the Hypothesis of the Lime-Magnesia Ratio, Dr. Chas. B. Lipman, University of California, Berkeley, Cal.

3. Relation of Type of Farming to Soil Fertility, D. A. Brodie, Office of Farm Management, U. S. Dept. Agr., Washington, D. C.

4. Soil Nitrogen from the Standpoint of Plant Nutrition, Dr. W. P. Kelley, Graduate School of Tropical Agriculture, University of California, Berkeley, Cal.

5. Business Session.

Tuesday Afternoon, August 10.

Joint Session.

1. The Effect of Time of Seeding on Rate of See ling Winter Wheat, Prof. W. M. Jardine, Experiment Station, Manhattan, Kans. (A. S. A.).

2. The Practical Application of Farm Management Principles, Mr. H. W. Jeffers, Plainsboro, N. J. (Amer. Farm-Mgmt. Asso.)

3. The Farmer's Response to Economic Forces, Prof. W. J. Spillman, Office of Farm Management, U. S. Dept. Agr. (Amer. Farm-Mgmt. Asso.)

4. Intensive Agricultural Practice of China and Japan, Prof. Alfred Vivian, College of Agriculture, Columbus, Ohio. (S. P. A. S.)

Tuesday Evening, August 10.

If a sufficient number of papers are available, a session will be arranged.

MEMBERSHIP CHANGES.

The membership reported in the May-June number of the Journal was 437. Since that time, 7 new members have been received, making the total at this date 444. The number of new members received in 1915 is now 78. The names of new members not previously reported, and recent changes of address are as follows:

New Members.

Beavers, J. C., Purdue Agr. Expt. Sta., La Fayette, Ind.
Gaddis, P. L., Hopt Farm, Cambridge, Nebr.
Holland, Robt. E., University Farm, Lincoln, Nebr.
Lora, Armando, Aguiar 47, Havana, Cuba.
Noyes, H. A., Purdue Agr. Expt. Sta., La Fayette, Ind.
Slipher, John A., Purdue University, La Fayette, Ind.
Spafford, R. R., University Farm, Lincoln, Nebr.

ADDRESSES CHANGED.

CLOTHIER, R. W., Office of Farm Management, U. S. Dept. Agr., Washington, D. C.
DELWICHE, E. J., Ashland, Wis.
JONES, J. W., Nephi Substation, Nephi, Utah.
KRAUSS, F. G., Supt. of Extension Work, Expt. Sta., Honolulu, Hawaii.
KLEIN, M. A., College of Agriculture, Univ. of Cal., Berkeley, Cal.
LIVINGSTON, GEORGE, Office of Markets, U. S. Dept. Agr., Washington, D. C.
MOOMAW, LEROY, Judith Basin Substation, Moccasin, Mont.

NOTES AND NEWS.

M. A. Brannon has resigned as president of the University of Idaho.

J. B. Davidson, professor of agricultural engineering in Iowa State College, has been elected to a newly established similar position in California. He will devote the greater part of his time to developing a testing plant at the University Farm at Davis to determine the fundamental reasons for the efficiency of farm machinery.

P. L. Gaddis has been appointed an assistant professor of agronomy in the Nebraska College of Agriculture. He will be engaged in extension work.

E. J. Iddings, animal husbandman of the Idaho college and station, has been made dean of the college to succeed W. L. Carlyle.

J. S. Jones, who has been chemist of the Idaho station for several years, was recently elected director of that station.

Millard A. Klein has been appointed instructor in soil chemistry and bacteriology in the University of California, effective July 1.

F. J. Krauss, formerly agronomist of the College of Agriculture of Hawaii, is now superintendent of agricultural extension in Hawaii, with headquarters at the experiment station, Honolulu.

George Livingston, for the past year acting head of the department of agronomy in Ohio State University, resigned in June to accept a position with the office of markets in the Federal Department of Agriculture. In his new position he will investigate the marketing of grain.

H. C. Price, who has been dean of the college of agriculture of Ohio State University since 1903, has resigned, effective at the end of the school year.

J. H. Shepperd, agriculturist of the North Dakota college and station and vice-director of the station, will in the future devote his entire time to the work of the station.

The Ohio legislature has passed a bill abolishing the Ohio Agricultural Commission, which had charge of all State work in agriculture, and replacing it by a State Board of Agriculture of 10 members, who will serve without compensation. The new board will have all the powers of the commission except the control of the experiment station, which is governed by a separate body. All extension and institute work will be conducted by Ohio State University. The bill becomes a law ninety days after it is signed by the Governor.

The Secretary of Agriculture, in accordance with the appropriation act for the Department of Agriculture for the current fiscal year, has established the States Relations Service. This service includes the Office of the Director, in charge of Dr. A. C. True; the Office of Experiment Stations, in charge of Dr. E. W. Allen; the Office of Extension Work in the South, in charge of Mr. Bradford Knapp; the Office of Extension Work in the North and West, in charge of Mr. C. B. Smith; and the Office of Home Economics, in charge of Dr. C. F. Langworthy. The work relating to agricultural instruction and farmers' institutes is to be included in the Office of the Director.

COMING EVENTS.

Under this caption it is proposed to keep standing a schedule of coming meetings of various organizations more or less closely connected with agronomy. Secretaries of such bodies are invited to furnish information regarding their meetings.

American Society of Agronomy.

Annual meeting, University of California, Berkeley, Cal., August 9–10, 1915. (In connection with meeting of Association of American Agricultural Colleges and Experiment Stations.)

American Farm-Management Association.

Berkeley, Cal., August 9–10, 1915.

Association of American Agricultural Colleges and Experiment Stations.

University of California, Berkeley, Cal., August 11–13, 1915.

Pan-American Scientific Congress.

Washington, D. C., December 27, 1915—January 8, 1916.

Society for the Promotion of Agricultural Science.

Berkeley, Cal., August 9–10, 1915.

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THE INFLUENCE OF CERTAIN ORGANIC MATERIALS UPON THE TRANSFORMATION OF SOIL NITROGEN.[1]

R. CLAUDE WRIGHT,

BUREAU OF PLANT INDUSTRY, U. S. DEPARTMENT OF AGRICULTURE.

INTRODUCTION.

In view of the fact that under ordinary farm practice much organic material in the form of fresh and rotted stable manure and green manure in various stages of growth is plowed into the soil each year, it seems of considerable importance that the influence of these and similar materials upon the nitrogen content of the soil should be more extensively studied. Further, the plowing under of straw and like material which, although not widely practiced, is somewhat extensively followed in the citrus belt of southern California, offers some interesting problems of practical importance along this line. The reason for this latter practice is to maintain in the soil a supply of organic material that is more or less resistant to the very rapid oxidation which occurs there.

A few investigators have studied the effects of various nitrogenous and non-nitrogenous organic materials upon plant growth, both in pots and in the field. Chirikov and Shmuk[2] added sugar, starch, and straw in amounts varying from 0.125 percent to 1.0 percent in sand cultures. It was found that the least growth of mustard was obtained in the presence of sugar, followed by starch and then straw. The inhibited growth was evidently due to the reduction of available

[1] Received for publication July 10, 1915.

[2] Chirikov, F. V., and Shmuk, A. A., Abstract in Monthly Bulletin of Agricultural Intelligence and Plant Diseases, 4 (1913), No. 10, p. 1528–9.

nitrogen to insoluble form. F. von May[3] reports an experiment in which rye straw, red clover hay, and cottonseed meal were plowed under singly and in combination. Potatoes were planted immediately thereafter. The results showed that nitrification or the rendering available of assimilable nitrogen was depressed by the presence of more or less nitrogen-free organic matter, such as straw in this case. The author suggests that the immediate appropriation of soluble nitrogen by microorganisms using the nitrogen-free substance as a source of energy is responsible for the depression of plant growth. Stutzer[4] added to pots growing buckwheat 1 percent each of starch and chopped straw. Both materials depressed the yield; however, when sodium nitrate was added, the growth was somewhat improved. E. von Seelhorst and W. Freckman[5] report a depressed growth of oats in pots containing additions of straw or strawy manure.

Green manures, when plowed under in an immature state, are not generally considered to be injurious to succeeding crops. Hutchinson and Milligan[6] report that the best results were obtained when *Crotalaria juncea* used as a green manure was turned under when still green and succulent. When plants four weeks old were turned under 67 percent of the nitrogen content was nitrified, while with plants ten weeks old only 34.5 percent was nitrified. Kellerman and Wright[7] report that when added to a California soil under laboratory conditions mature barley straw reduced the nitrate content of the soil from 0.445 to 0.247 mg. per gram of soil, while additions of immature green barley and green vetch caused a rapid increase in the nitrate. When 1 percent of straw was added to the same soil in pots growing orange or grapefruit seedlings, marked evidences of nitrogen starvation soon became evident by a yellowing of the leaves and suspended growth. When 0.02 percent of nitrogen as sodium nitrate was added with the straw, the seedlings remained normal. In pots of ordinary greenhouse potting soil 1 percent quantities of straw and cellulose produced very marked symptoms of nitrogen starvation on grapefruit seedlings, while the same quantities of green sweet clover and green grass produced slight chlorotic symptoms only the

[3] May, F. von, Mitt. Landw. Lehrkanz. K. K. Hochsch. Bodenkul. Wien, 2 (1914), No. 3, p. 433–54.

[4] Stutzer, A., Jour. Landw., 55 (1907), No. 1, p. 81–91.

[5] Seelhorst, E. von, and Freckman, W., Jour. Landw., 52 (1904), No. 1–2, p. 163–71.

[6] Hutchinson, C. M., and Milligan, S., Agr. Research Inst., Pusa, Bul. 40 (1914), pp. 31.

[7] Kellerman, K. F., and Wright, R. Claude, U. S. Dept. Agr., Jour. Agr. Research, Vol. II, No. 2, p. 101–13. 1914.

first few days, followed by a return to the normal condition of healthy growth. At the close of the experiment, after 166 days, the seedlings treated with straw showed evidences of not recovering from the treatment.

Research.

Certain experiments were conducted by the author in order to follow the various stages of nitrogen transformation in soil in the presence of a variety of organic material. Duplicate analyses of samples were made periodically while the soils were kept under control laboratory conditions at a temperature ranging from 28 to 30° C. All nitrates were determined by the modified Tieman-Schulze method.[8] Total nitrogen determinations were made by the Kjeldahl-Gunning-Jodlbauer method, using the sulphate mixture during digestion recommended by Lipman and Sharp.[9]

In the first experiment a study was made of the effect upon nitrification in soil of 2 percent and 5 percent quantities of dried fresh and rotted stable manure and mature wheat straw. This was carried on in both sandy loam and clay loam soil from the Arlington Farm near Rosslyn, Va. As these soils both gave an acid reaction, this was corrected with 1 percent of calcium carbonate. A large quantity of the air-dry soil was first screened and thoroughly mixed and 2,000 gram quantities weighed out into large battery jars. After the required amount of dried and finely ground organic material and 1.6 gm. of ammonium sulphate had been mixed in, the samples were brought to the optimum moisture condition and incubated eleven weeks. The moisture condition was maintained by a layer of wet cotton kept over the jars. Every week the contents of each jar was thoroughly mixed and 100 grams removed for analysis. After four weeks' incubation, the supply of ammonium sulphate having become exhausted, a new supply was added. The results of the analyses are shown in Table 1.

The results of periodic analyses of these samples shown in Table 1 indicate that during the first four weeks nitrification in sandy loam was stimulated by 2 percent of fresh manure and slightly depressed by 5 percent as compared with that in the control samples. In clay loam nitrification was somewhat depressed by 2 percent and greatly depressed by 5 percent of fresh manure. Rotted manure in both soils stimulated nitrification, with little difference shown between 2 percent and 5 percent amounts. In the presence of straw, nitrification in both

[8] Centbl. Bakt., Abt. II, Bd. 38 (1913), p. 14–25.

[9] Lipman, C. B., and Sharp, L. T., Centbl. Bakt., Abt. II, Bd. 35 (1912), p. 648.

types of soil was totally absent except with 2.0 percent in clay loam where slight nitrification was evident.

TABLE 1.—*Nitrification in the Presence of Fresh Manure, Rotted Manure, and Straw in Sandy Loam and Clay Loam, Expressed in Milligrams of Nitrate Nitrogen per Gram of Dry Soil.*

SANDY LOAM.

Treatment.	1 Week.	2 Weeks.	3 Weeks.	4 Weeks.	5 Weeks.	6 Weeks.	7 Weeks.	8 Weeks.	9 Weeks.	10 Weeks.	11 Weeks.
	Mg.	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*
Control	0.004	0.015	0.035	0.048	.....	0.328	0.344	0.355	0.342	0.349	0.368
+2% fresh manure	0.013	0.037	0.067	0.086	0.067	0.185	0.340	0.437	0.480	0.520	0.508
+5% " "	0.006	0.020	0.024	0.040	0.111	0.388	0.416	0.409	0.435	0.426	0.437
+2% rotted manure	0.005	0.053	0.074	.....	0.287	0.530	0.525	0.532	0.457	0.527	0.526
+5% " "	0.025	0.068	0.074	0.105	0.262	0.429	0.427	0.417	0.418	0.445	0.444
+2% straw	0.002	0.000	0.000	0.000	0.007	0.148	0.216	0.163	0.169	0.192	0.227
+5% "	0.000	0.000	0.000	0.000	0.000	0.090	0.160	0.187	0.182	0.189	0.193

CLAY LOAM.

Control	0.031	0.100	0.115	0.149	0.332	0.575	0.633	0.610	0.625	0.615	0.630
+2% fresh manure	0.039	0.095	0.109	0.130	0.213	0.449	0.643	0.640	0.640	0.625	0.675
+5% " "	0.014	0.009	0.015	0.033	0.152	0.445	0.475	0.465	0.420	0.494	0.460
+2% rotted manure	0.053	0.170	0.161	0.212	0.000	0.580	0.725	0.730	0.720	0.790	0.734
+5% " "	0.093	0.183	0.179	0.200	0.000	0.666	0.770	0.725	0.750	0.730	0.755
+2% straw	0.015	0.010	0.016	0.029	0.144	0.362	0.490	0.480	0.465	0.512	0.518
+5% "	0.000	0.000	0.000	0.000	0.027	0.210	0.305	0.312	0.306	0.332	0.372

After the second addition of ammonia, nitrification became more rapid in all samples. This was probably due to the fact that decomposition of the carbonaceous materials was well advanced.

After eleven weeks' incubation, both types of soil treated with rotted manure contained the greatest amount of nitrate nitrogen. In sandy loam treated with fresh manure there was almost as much nitrate as with rotted manure present. More nitrate was present with 2 percent than with 5 percent fresh manure. In clay loam there was considerably less nitrate with fresh manure than with rotted manure. With 5 percent there was less than in the controls. All samples treated with straw contained less nitrate than the controls. In conclusion, rotted manure stimulated nitrification from the first. Fresh manure and straw at first inhibited nitrification until decomposition was well advanced.

In the next experiment, duplicate 2 percent quantities of dried and ground fresh and rotted horse manure, straw, and starch were added to 500 gram samples of a greenhouse bench soil to which 0.4 percent of nitrogen as potassium nitrate had been added. The required moisture was added and samples incubated seven weeks. The fresh and rotted horse manures were from the same original sample, which some months previous to the experiment had been divided and part immediately dried, while the rest was allowed to decay in a large glass jar with frequent moistening and stirring. Nitrate determinations were made each week with the exception of the fifth week. At the end of the fourth week a second addition of organic material was made. The results from this experiment are shown in Table 2.

TABLE 2.—*Nitrate Reduction in the Presence of 2 Percent Quantities of Fresh and Rotted Manure, Straw, and Starch, Expressed in Milligrams of Nitrate Nitrogen per Gram of Dry Soil.*

	Start.	1 Week.	2 Weeks.	3 Weeks.	4 Weeks.	6 Weeks.	7 Weeks.
	Mg.	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*
Control	0.550	0.550	0.562	0.560	0.545	0.563	0.530
+Rotted manure	0.550	0.546	0.618	0.565	0.557	0.595	0.600
+Fresh manure	0.550	0.465	0.455	0.448	0.437	0.172	0.160
+Straw	0.550	0.362	0.292	0.315	0.320	0.000	0.000
+Starch	0.550	0.074	0.094	0.155	0.210	0.000	0.000

Table 2 shows that while there was some fluctuation in the nitrate content of samples containing rotted manure, nitrate reduction did not take place. A reduction in nitrate, however, was evident in the presence of fresh manure, straw, and starch. This apparently continued until a certain stage of decomposition was reached, when, where straw and starch had been added, nitrification commenced. On the addition of a fresh supply of organic matter rapid nitrate reduction again took place until in samples containing straw and starch all nitrate disappeared.

The next experiment was conducted to determine the effect of 2.0 percent quantities of cellulose (finely cut filter paper), glucose, starch, and fresh horse manure (dried and ground) upon the nitrification of peptone in the soil. Duplicate quantities of these materials and 0.48 grams of peptone were added to 400-gram samples of clay loam soil similar to that used in the first experiment, and a sandy loam soil from an alfalfa plat on the experiment farm near Fallon, Nev. Samples were incubated eight weeks. Nitrate determinations were made each week and are reported in Table 3.

TABLE 3.—*Nitrification in District of Columbia and in Nevada Soil in the Presence of 2 Percent Quantities of Cellulose, Glucose, Starch, and Fresh Manure, Expressed in Milligrams of Nitrate Nitrogen per Gram of Dry Soil.*

Treatment.	Start.	1 Week.	2 Weeks.	3 Weeks.	4 Weeks.	6 Weeks.	8 Weeks.
	Mg.	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*
District of Columbia Soil.							
Control	0.013	0.033	0.085	0.130	0.130	0.173	0.216
+Cellulose	0.013	0.000	0.000	0.000	0.000	0.070	0.079
+Glucose	0.013	0.000	0.000	0.000	0.000	0.022	0.044
+Starch	0.013	0.000	0.000	0.000	0.000	0.028	0.053
+Fresh manure	0.013	0.013	0.015	0.021	0.082	0.182	0.207
Nevada Soil.							
Control	0.000	0.006	0.034	0.093	0.139	0.210	0.271
+Cellulose	0.000	0.000	0.000	0.000	0.000	0.000	0.000
+Glucose	0.000	0.000	0.000	0.000	0.000	0.008	0.038
+Starch	0.000	0.000	0.000	0.000	0.000	0.000	0.000
+Fresh manure	0.000	0.000	0.000	0.000	0.000	0.093	0.149

Examination of the results in Table 3 show that nitrification proceeded very slowly in District of Columbia soil with fresh manure until after three weeks, when it became more rapid. Where cellulose, glucose and starch were added the original nitrate present was reduced and no nitrification took place until after four weeks. In Nevada soil nitrification took place only after four weeks in soil containing fresh manure and glucose, while none took place with cellulose or starch present. It might be noted here that at the end of the first week tests for glucose and starch showed these materials had disappeared.

A complementary experiment to the preceding was conducted in which a similar series was run with 0.2 percent of potassium nitrate in place of peptone. From Table 4 it may be seen that, while the nitrate in the controls in District of Columbia soil fluctuated somewhat, there was no great change in the amount. With cellulose, glucose, and starch, nitrate was entirely reduced followed by a commencement of nitrification where glucose and starch were present. With fresh manure present, the nitrate was partially reduced, then nitrification commenced. In sandy loam or Nevada soil nitrate in the control samples remained almost unchanged. It was entirely reduced in presence of glucose and starch, and nearly all reduced in presence of cellulose, but the process was more slow. Not quite half the nitrate was reduced in presence of fresh manure. Here also the process was slow. Where cellulose and starch were present nitrification set in after three weeks. A test for glucose and starch after the first week showed these substances to have disappeared.

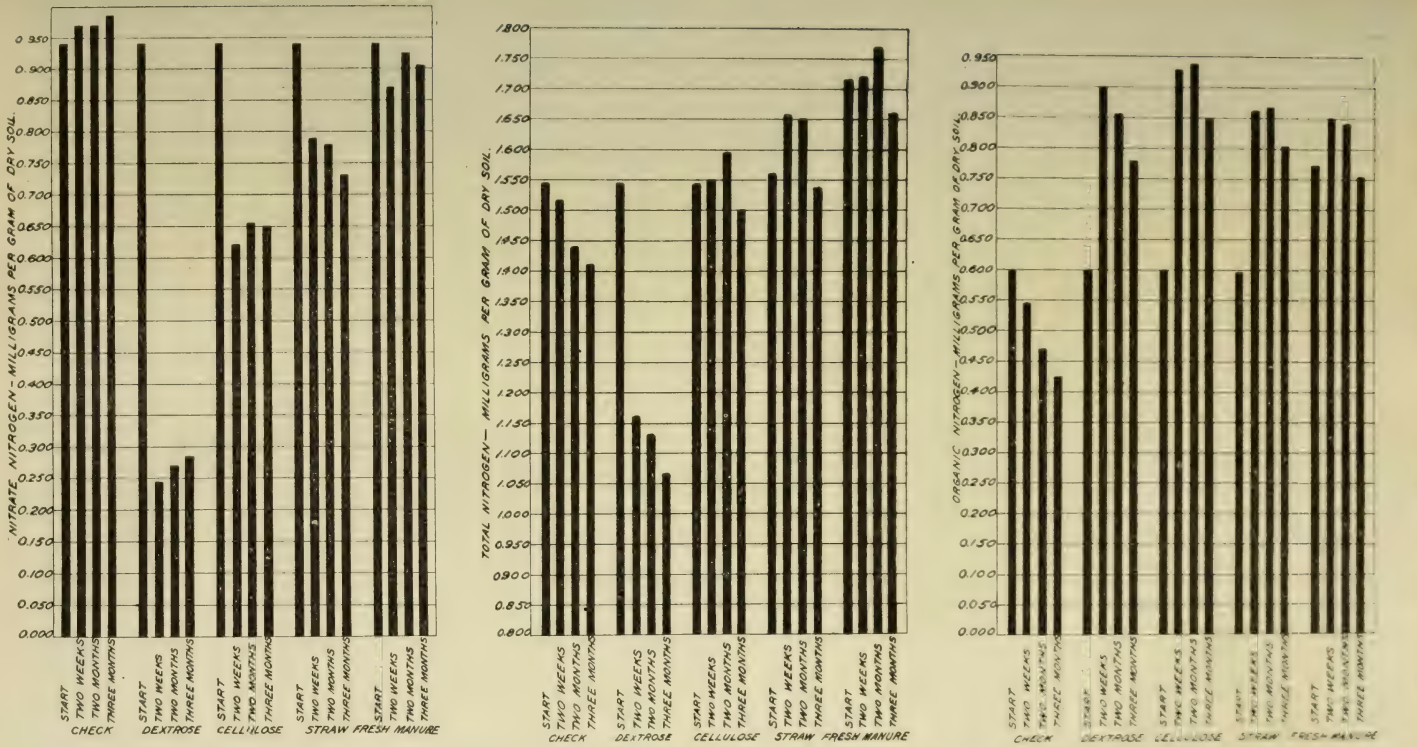

FIG. 6.—Influence upon nitrate nitrogen (left), total nitrogen (center), and organic nitrogen (right) of 2 percent quantities of dextrose, cellulose, straw, and fresh manure.

TABLE 4.—*Nitrification in District of Columbia and Nevada Soils + Potassium Nitrate in the Presence of 2 Percent Quantities of Cellulose, Glucose, Starch, and Fresh Manure.*

DISTRICT OF COLUMBIA SOIL.

Treatment.	Start.	1 Week.	2 Weeks.	3 Weeks.	4 Weeks.	6 Weeks.	8 Weeks.
	Mg.	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*
Control	0.268	0.249	0.253	0.262	0.267	0.237	0.317
+Cellulose	0.268	0.051	0.028	0.000	0.000	0.000	0.000
+Glucose	0.268	0.000	0.003	0.010	0.020	0.065	0.072
+Starch	0.268	0.000	0.000	0.000	0.000	0.007	0.012
+Fresh manure	0.268	0.117	0.169	0.173	0.189	0.184	0.220
NEVADA SOIL.							
Control	0.255	0.251	0.252	0.254	0.256	0.269	0.253
+Cellulose	0.255	0.204	0.119	0.094	0.085	0.076	0.080
+Glucose	0.255	0.007	0.000	0.000	0.000	0.000	0.000
+Starch	0.255	0.201	0.084	0.000	0.000	0.000	0.000
+Fresh manure	0.255	0.214	0.177	0.153	0.157	0.143	0.157

Unfortunately in the former experiments it was impractical to obtain reliable total nitrogen determinations. It is apparent that parallel total nitrogen and nitrate determinations are important to follow the complete transformation of nitrogen in the presence of various carbonaceous materials in the soil.

In the following experiment 500-gram samples of a soil from a productive orange grove near Riverside, Cal., were mixed with duplicate 2 percent quantities of mature barley straw, fresh horse manure, cellulose (finely cut filter paper), and dextrose. The straw and manure had previously been dried and ground. Potassium nitrate was added to each, bringing the nitrate nitrogen content to 0.942 milligrams per gram of dry soil. Samples were brought to the optimum moisture condition and incubated three months in glass fruit jars with perforated tops. Parallel total nitrogen and nitrate determinations were made in two weeks, two months, and three months. The results are shown in Table 5 and in figure 6. The results in this and following experiments given as organic nitrogen were obtained by subtracting nitrate nitrogen from total nitrogen in each case.

As shown in Table 5 and figure 6, even in the presence of an excess of nitrate some nitrification occurred in the control samples. This was accompanied by a decrease in organic nitrogen, part of which was evidently converted into nitrate. However, there was an actual loss of total nitrogen equivalent to 0.132 mg. per gram of dry soil. With dextrose present there was a marked

TABLE 5.—*Nitrogen Transformation in Presence of 2 Percent Quantities of Dextrose, Cellulose, Straw and Fresh Manure, Expressed in Milligrams per Gram of Dry Soil.*

NITRATE NITROGEN.

	Start.	2 Weeks.	2 Months.	3 Months.
Control	0.942	0.970	0.970	0.985
+Dextrose	0.942	0.243	0.270	0.286
+Cellulose	0.942	0.622	0.655	0.650
+Straw	0.942	0.790	0.780	0.730
+Fresh manure	0.942	0.872	0.925	0.907

TOTAL NITROGEN.

Control	1.544	1.517	1.442	1.411
+Dextrose	1.544	1.158	1.132	1.065
+Cellulose	1.544	1.551	1.593	1.499
+Straw	1.558	1.655	1.649	1.534
+Fresh manure	1.716	1.725	1.771	1.660

ORGANIC NITROGEN.

Control	0.602	0.547	0.472	0.426
+Dextrose	0.602	0.915	0.853	0.779
+Cellulose	0.602	0.929	0.938	0.849
+Straw	0.616	0.865	0.869	0.804
+Fresh manure	0.774	0.853	0.846	0.753

reduction of nitrate, amounting after two weeks to 0.699 mg. per gram. Of this nitrate nitrogen, 0.303 mg. per gram was converted into organic nitrogen—probably existing in some form of protein within the cell walls of the bacteria using this as a source of energy. Here also examination of the total nitrogen results show a real loss of 0.386 mg. per gram of dry soil. After two weeks there occurred a slight increase in nitrate accompanied by a decrease in organic nitrogen. Much of the nitrogen lost from the soil probably escaped as ammonia, as its odor was noticeable during sampling. With cellulose, straw and fresh manure present the greatest reduction of nitrate occurred in presence of cellulose, amounting in two weeks to 0.320 mg. per gram, followed by little change. With straw this reduction amounted to 0.152 mg., and with fresh manure only 0.07 mg. per gram. Practically all loss of nitrate can be accounted for in the gain in organic nitrogen. There was some gain in total nitrogen with these substances present, possibly accounted for through a fixation of nitrogen. Even in the presence of an excessive amount of nitrate in all samples the only serious loss of nitrogen occurred with dextrose present amounting to 0.479 mg. nitrogen per gram of soil.

In the next experiment 800-gram samples of a silty loam soil from the Potomac River flats, District of Columbia, and a sandy loam soil from near Riverside, Cal., were mixed with duplicate 1 percent

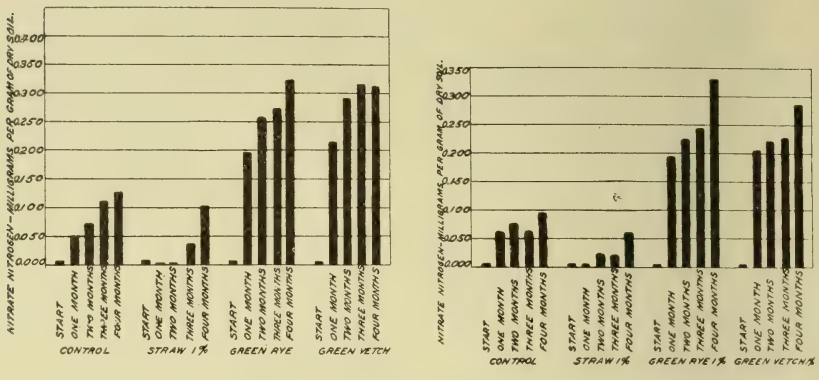

FIG. 7.—Influence upon nitrate nitrogen of 1 percent quantities of straw, green rye, and green vetch in California soil (left) and District of Columbia soil (right).

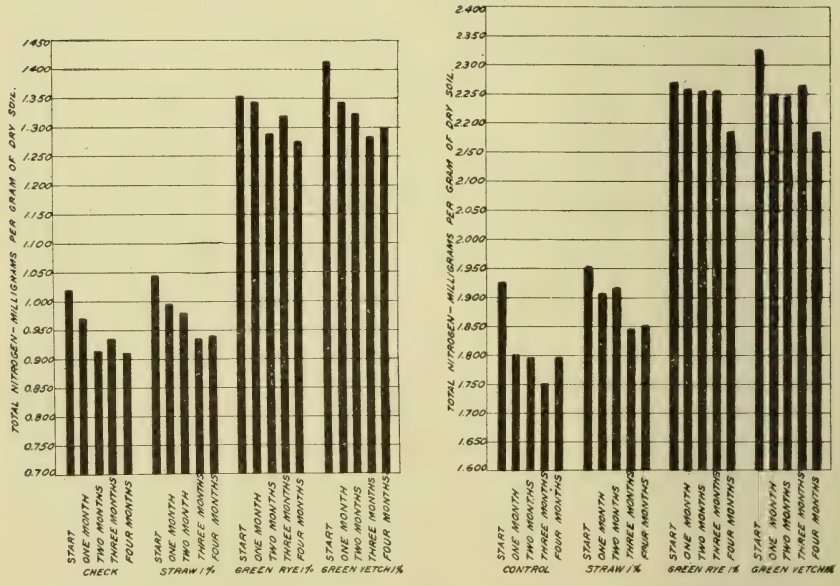

FIG. 8.—Influence on total nitrogen in 1 percent quantities of straw, green rye, and green vetch in California soil (left) and District of Columbia soil (right).

quantities of mature wheat straw, young green rye, and green vetch. All materials were previously dried and ground fine. Samples were

brought to the proper moisture condition and incubated four months. No nitrate was added. The original nitrate nitrogen present in both soils amounted to only 0.006 mg. per gram. Total nitrogen and nitrate nitrogen determinations were made each month. The results are shown in Table 6 and in figures 7 to 9.

TABLE 6.—*Nitrogen Transformation in Presence of 1 Percent Quantities of Straw, Green Rye, and Green Vetch, Expressed in Milligrams per Gram of Dry Soil.*

NITRATE NITROGEN.

Soil and Treatment.	Start.	1 Month.	2 Months.	3 Months.	4 Months.
California Soil:					
Control	0.006	0.045	0.071	0.109	0.127
+Straw	0.006	0.000	0.000	0.037	0.102
+Green rye	0.006	0.194	0.255	0.272	0.323
+Green vetch	0.006	0.213	0.290	0.316	0.312
District of Columbia Soil:					
Control	0.006	0.059	0.075	0.062	0.095
+Straw	0.006	0.005	0.023	0.021	0.060
+Green rye	0.006	0.195	0.226	0.245	0.332
+Green vetch	0.006	0.207	0.224	0.228	0.287

TOTAL NITROGEN.

California Soil:					
Control	1.019	0.968	0.918	0.935	0.909
+Straw	1.047	0.995	0.981	0.933	0.939
+Green rye	1.355	1.343	1.289	1.322	1.273.
+Green vetch	1.413	1.344	1.324	1.287	1.300
District of Columbia Soil:					
Control	1.926	1.802	1.797	1.752	1.795
+Straw	1.951	1.905	1.918	1.846	1.850
+Green rye	2.268	2.260	2.254	2.255	2.185
+Green vetch	2.325	2.252	2.245	2.264	2.184

ORGANIC NITROGEN.

California Soil:					
Control	1.013	0.923	0.847	0.826	0.773
+Straw	1.041	0.995	0.981	0.896	0.834
+Green rye	1.348	1.139	1.034	1.017	0.950
+Green vetch	1.417	1.131	1.034	0.971	0.987
District of Columbia Soil:					
Control	1.920	1.743	1.722	1.690	1.700
+Straw	1.945	1.900	1.895	1.825	1.790
+Green rye	2.262	2.165	2.028	2.011	1.853
+Green vetch	2.319	2.045	2.021	2.036	1.897

A study of results shown in Table 6 and figures 7 to 9 show that nitrification took place in all control samples, also a loss in total nitrogen amounting to 0.110 mg. per gram of California soil and 0.131 mg. per gram of District of Columbia soil. In California soil with straw present the original nitrate nitrogen was reduced and no

nitrification occurred until the third month. In District of Columbia soil slight nitrification commenced the second month. In both soils there was some loss in total nitrogen, amounting to 0.108 mg. per

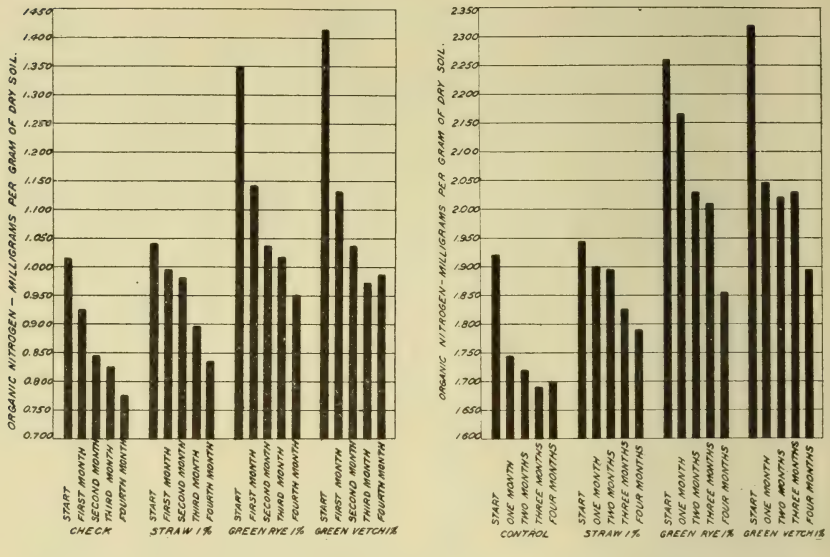

FIG. 9.—Influence upon organic nitrogen of 1 percent quantities of straw, green rye, and green vetch in California soil (left) and District of Columbia soil (right).

gram of California soil and 0.101 mg. in District of Columbia soil. With green rye and green vetch present rapid nitrification took place the first month, accompanied by a rapid corresponding decrease in organic nitrogen. This process continued less rapidly after the first month. There was a small loss in total nitrogen in both soils with green rye present, amounting to 0.082 mg. per gram of California soil and 0.083 mg. in District of Columbia soil. With green vetch the loss was greater, amounting to 0.113 mg. per gram of California soil and 0.141 mg. in District of Columbia soil.

Parallel with the foregoing experiment a similar one was conducted on California and District of Columbia soils taken from practically the same localities. The exception was that in this series potassium nitrate was added to all samples, bringing the nitrate nitrogen content up to 0.520 mg. per gram of dry soil. In all other respects the experiment was conducted in identically the same manner. The results are shown in Table 7 and figures 10 to 12.

TABLE 7.—*Nitrogen Transformation in Presence of 1 Percent Quantities of Straw, Green Rye, and Green Vetch, Expressed in Milligrams per Gram of Dry Soil.*

NITRATE NITROGEN.

Soil and Treatment.	Start.	1 Month.	2 Months.	3 Months.	4 Months.
California Soil +Nitrate:					
Control	0.520	0.527	0.590	0.561	0.550
+Straw	0.520	0.473	0.482	0.507	0.535
+Green rye	0.520	0.515	0.625	0.650	0.700
+Green vetch	0.520	0.492	0.650	0.670	0.710
District of Columbia Soil +Nitrate:					
Control	0.520	0.525	0.560	0.527	0.585
+Straw	0.520	0.452	0.460	0.433	0.512
+Green rye	0.520	0.620	0.677	0.032	0.767
+Green vetch	0.520	0.640	0.640	0.737	0.775

TOTAL NITROGEN.

California Soil +Nitrate:					
Control	1.487	1.470	1.417	1.427	1.411
+Straw	1.515	1.509	1.460	1.427	1.422
+Green rye	1.820	1.765	1.761	1.755	1.739
+Green vetch	1.880	1.725	1.769	1.744	1.786
District of Columbia Soil +Nitrate:					
Control	2.390	2.355	2.374	2.238	2.217
+Straw	2.421	2.339	2.326	2.310	2.315
+Green rye	2.740	2.611	2.721	2.634	2.655
+Green vetch	2.792	2.736	2.718	2.702	2.637

ORGANIC NITROGEN.

California Soil +Nitrate:					
Control	0.967	0.943	0.827	0.866	0.861
+Straw	0.995	1.036	0.978	0.920	0.887
+Green rye	1.300	1.250	1.136	1.105	1.039
+Green vetch	1.360	1.233	1.119	1.074	1.076
District of Columbia Soil +Nitrate:					
Control	1.870	1.830	1.814	1.711	1.652
+Straw	1.901	1.887	1.866	1.877	1.803
+Green rye	2.220	1.991	2.044	2.002	1.888
+Green vetch	2.272	2.096	2.078	1.965	1.862

The results in Table 7 show that not so rapid nitrification as in the former experiment took place in either controls or where green rye and green vetch were present. With straw present some nitrate was reduced, but this was practically recovered by the end of the fourth month. The greatest reduction occurred in District of Columbia soil. In control samples there was not so much of a loss of

total nitrogen in California soil as in the former series, while the loss was greater in District of Columbia soil. As in the former series the

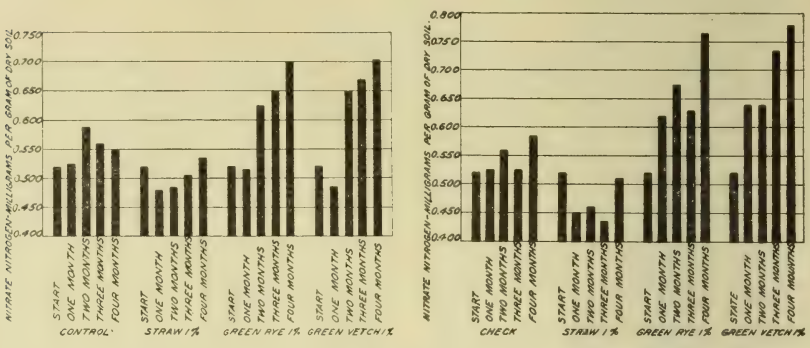

FIG. 10.—Influence on nitrate nitrogen of 1 percent quantities of straw, green rye, and green vetch in California soil + nitrate (left) and District of Columbia soil + nitrate (right).

loss in total nitrogen was greater in District of Columbia soil, amounting to 0.173 mg. per gram against 0.076 mg. per gram in California

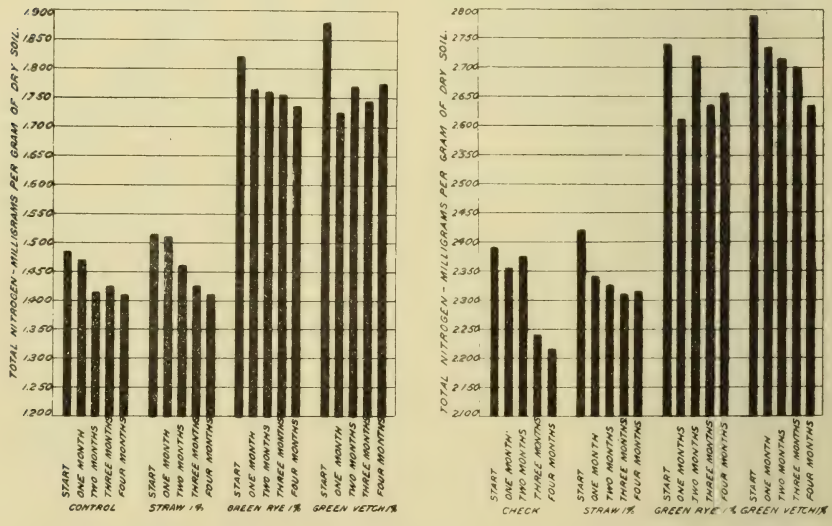

FIG. 11.—Influence upon total nitrogen of 1 percent quantities of straw, green rye, and green vetch in California soil + nitrate (left) and District of Columbia soil + nitrate (right).

soil. With straw present the difference in loss in total nitrogen amounted to but little between California and District of Columbia

soil with and without nitrate present. When green rye was added there was practically no difference between the two soils in the amount of nitrogen lost. However, in California soil the loss was greater than in the former series, while in District of Columbia soil the loss was practically the same, although the results were rather fluctuating and uncertain. With green vetch present the loss was greater in District of Columbia soil, amounting to 0.155 mg. per gram. That in California soil amounted to 0.094 mg. per gram. The loss was also greater than when no nitraate was present, while in California soil it was less.

In the last experiment reported upon, 400-gram samples of a sandy loam soil from near Riverside, Cal., were mixed with duplicate 1 and 0.5 percent quantities of mature barley straw. Enough potassium nitrate was added to bring the nitrate content to 0.230 mg. per gram of dry soil. Samples were incubated one month. The results are shown in Table 8.

TABLE 8.—*Transformation of Nitrogen in Presence of 0.5 and 1 Percent Quantities of Straw, Expressed in Milligrams per Gram of Dry Soil.*

Treatment.	Start.	1 Month.
Nitrate Nitrogen.		
Control	0.230	0.223
+ 0.5 percent straw	0.230	0.137
+ 1 percent straw	0.230	0.133
Total Nitrogen.		
Control	0.946	0.784
+ 0.5 percent straw	0.959	0.932
+ 1 percent straw	0.967	0.826

Table 8 shows that the amount of nitrate reduced by 1 and 0.5 percent quantities of straw was practically the same. In total nitrogen there was a loss of 0.141 mg. per gram with 0.5 percent of straw against 0.280 mg. per gram with 1 percent. The loss with both quantities of straw present was less than in the controls.

CONCLUSIONS.

In the light of the foregoing it seems probable that in agricultural practice the plowing under, in an undecayed state, of straw or strawy material such as old hay, litter, leaves, stalks, strawy manure, fresh stable manure, and even green manures or cover crops that have been allowed to become mature or nearly so, will serve to reduce the quantity of available nitrogen in a soil. When such a practice is

followed only during fall plowing and in a region with a fairly open winter, it would be safe to say that a sufficently advanced stage of decomposition would be reached by spring not to interfere with

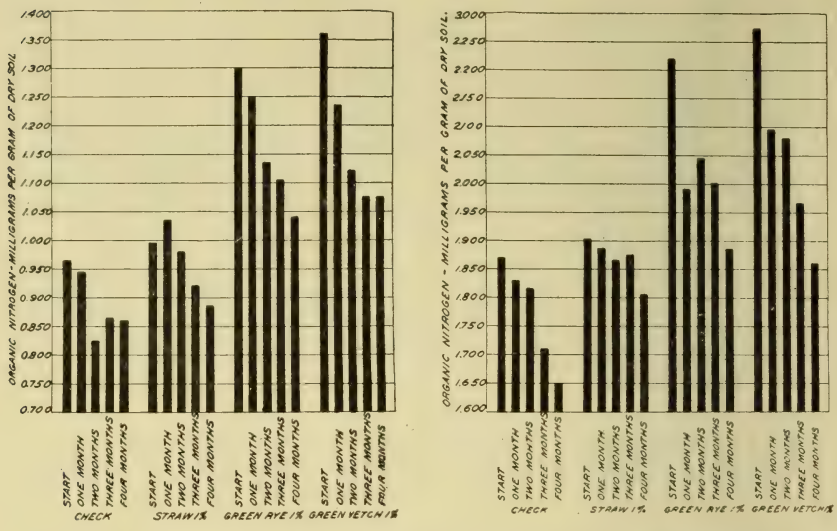

FIG. 12.—Influence upon organic nitrogen of 1 percent quantities of straw, green rye, and green vetch in California soil + nitrate (left) and District of Columbia soil + nitrate (right).

normal nitrification. Furthermore there probably would be little or no leaching away of soluble nitrogen during the fall and winter rains.

Plowing under of green manures presents a different problem because very little resistant cellulose material is added. Such succulent green material is readily attacked by saprophytic microorganisms and rather rapid decay accompanied by vigorous nitrification takes place, thus maintaining the supply of available nitrogen.

FIG. 1.—Two heads each, face and edge views, of New Columbia wheat, C. I. No. 3476, ♀ parent (as grown at Arlington, 1913–14); F_1 of artificial wheat-rye hybrid, 1319a (as grown at Arlington, 1913–14); rye, C. I. No. 132, ♂ parent (as grown at Ithaca, N. Y., 1911–12).

FIG. 2.—Two heads each, face and edge views, of Purple Straw wheat, C. I. No. 1915 (left), as grown in the plat at Arlington, 1913–14, near the hybrid plant; and Rimpau rye, C. I. No. 126 (right), as grown in 1911, under favorable environment; also, three heads, face and edge views, of the natural wheat-rye hybrid No. 1 (center). The Rimpau variety of rye grew not far from wheat, C. I. No. 1915, the previous year, and is shown here for comparison.

FIG. 1.—Two heads each, face and edge views, of Rimpau rye (same heads as in Pl. II, fig. 2); F_1 of natural wheat-rye hybrid No. 2; and Purple Straw wheat, C. I. No. 1915, as grown in the plat at Arlington near the hybrid plant, 1913–14.

FIG. 2.—One head each, edge view, of Dawson Golden Chaff wheat, C. I. No. 1733, as grown in the plat at Arlington, 1913–14, near the hybrid; F_1 of natural wheat-rye hybrid No. 3; and Rimpau rye (one of heads shown in Pl. II, fig. 2, and Pl. III, fig. 1).

NATURAL WHEAT-RYE HYBRIDS.[1]

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INTRODUCTION.

Artificial hybrids of rye on wheat have been made by many different plant breeders. The natural hybrid, however, apparently has been observed but seldom. The only reported intance of a possible natural wheat-rye hybrid, so far as the writer has found, is that cited by Fruwirth[2] (p. 184) as follows:

"Miczynski ("Kosmos" r. 30. Lwów. 1905) harvested some open fertilized seeds which gave when grown individuals which by their long, pressed-together glumes and their manner of standing open when in bloom were recognized as hybrids. These were, however, more similar to wheat and were not pubescent below the head."

The original article cited is not in the Congressional Library or in any other American library so far as ascertained, and has not been seen by the writer. It is possible that these plants grown by Miczynski were natural wheat-rye hybrids, although the writer has never observed wheat-rye hybrids that were not pubescent below the head.

In the summer of 1914 four separate instances of natural wheat-rye hybrids came to the notice of the writer. Three plants were observed on Arlington Farm, Rosslyn, Va., one by Mr. H. P. Ames, one by Mr. T. R. Stanton, and one by the writer. Two heads, also undoubtedly wheat-rye hybrids, were sent to the writer in June, 1914, by L. Robinson, of Brush Creek, Tenn., who writes: "Will you please tell me what this is? I pulled it out of a field of wheat. It has the appearance of wheat and rye both."

DESCRIPTION OF ARTIFICIAL HYBRID.

As a basis for the examination of these plants which are believed to be natural wheat-rye hybrids, comparison with an artificial hybrid produced by the writer will be made. In the spring of 1913, 11 flowers

[1] Presented at the eighth regular meeting of the Washington (D. C.) Section of the American Society of Agronomy, March 9, 1915.

[2] Fruwirth, C., Die Züchtung der landwirtschaftlichen Kulturpflanzen, Band 4, pp. xvi + 460. Berlin, 1910.

on a plant of the common red winter wheat, New Columbia, growing in a greenhouse of the U. S. Department of Agriculture, were emasculated, and two days later these flowers were pollinated with rye pollen from a plant of common rye growing in the same greenhouse. Four seeds were secured from this cross, and from one of these a plant was produced the following season (1914) in the field nursery at Arlington Farm. The data on the wheat-rye hybrid given herewith were taken on this plant. The wheat data were taken on plants produced from seed from the plant on which the cross was made, sown in the nursery at the same time and near the seed secured by this hybridization. The rye data were taken on the heads of the plant which produced the seed from which the pollen parent was grown. This "grandmother" plant, as it may be called, was found growing as a volunteer on waste land at Ithaca, N. Y., in 1912, therefore being grown in a different environment and in a different year from the wheat parent and the hybrid. The fundamental botanical characters, however, were doubtless not modified thereby, although some dimensions were probably somewhat modified. Typical heads of each of these parental forms on which the notes were made and of the hybrid are shown in Plate II, figure 1.

The heads of the wheat-rye hybrid are longer, narrower and less dense than those of the wheat parent, and are in the case under consideration completely sterile. Wheat-rye hybrids seldom bear seed.

The spikelets of wheat are 3- to 5-flowered; of rye 2-, rarely 3-flowered; while the hybrid is 3- to 5-flowered. The average number of spikelets on 10 heads of the wheat and rye parents were 21.2 and 27.6 respectively, on the hybrid 24.7.

The peduncle of wheat is hollow and smooth; of rye, solid, hairy, rough, and small in comparison with wheat; while the hybrid is either solid in the smaller culms, or with much thickened walls but hollow in the larger culms; also hairy and rough, but less so than rye, and is also about intermediate in size.

The glumes of wheat are ovate, nearly as large as the lemmas, several-nerved; those of rye much smaller than the lemmas, linear, one-nerved. The hybrid resembles the wheat parent very much in glume character, but is modified to some extent by the rye, the glumes being ovate but with sides more flattened than in wheat, and approaching the lemmas in size, but not so closely as in wheat.

The lemmas of wheat are ovate, and keeled only at the apex, while those of rye are lanceolate, keeled from apex to base, with the keel ciliate. The hybrid resembles wheat more, but the shape and keel

have been modified by rye, the latter extending farther toward the base and standing out more strongly. The lemma nerves of the hybrid are much like those of wheat.

The floral envelopes of the wheat are pubescent. The glumes of the rye are scabrous, the short stiff hairs decreasing from apex to base, while the lemmas are smooth except on keels and margins, which are ciliate. The glumes of the hybrid are pubescent, while the lemmas are pubescent near the apex and on the margins and scabrous elsewhere.

The awns in the wheat under discussion increase in length from about ½ mm. on the basal spikelets to 10–15 mm. on the apical; those of rye increase in length from 2–7 mm. on the lower spikelets to 35–40 mm. on the middle, then decrease to 5–10 mm. on the apical. Those of the hybrid increase in length from about 1 mm. on the basal spikelets to about 30 mm. on the apical, thus resembling wheat in the manner of increase, but attaining nearly the full length of the longest rye awns.

We may say then that the hybrid is distinguished from (1) both parents by its sterility, head-shape, general appearance and intermediacy in many characters; (2) from rye very distinctly by the shape and character of the glumes and lemmas and by its 3- to 5-flowered spikelets; and (3) from wheat very distinctly by the solid or thick-walled, hairy, rough peduncle.

The plants found in the summer of 1914 in the wheat plats at Arlington and the heads sent to the writer from Tennessee will now be considered. Data will be given on each of these and comparisons made with the known hybrid described above, showing why they are believed to be hybrids between wheat and rye.

Natural Wheat-Rye Hybrid No 1.

This natural wheat-rye hybrid was found in 1914 at Arlington Farm, Rosslyn, Va., in a plat of the Purple Straw wheat. This wheat had been in plat tests six years or more on this farm. In the previous year the wheat with which this plat was sown grew not more than 30 feet from a plat of rye. It is also possible that a few stray rye plants had grown in the plat of wheat or in the road bordering the end of the wheat plat. For the purpose of comparison a wheat plant growing near the hybrid was preserved. The principal culm of this wheat plant was as tall as any growing in the vicinity. but the main culm of the hybrid was about 4 inches taller. In fact,

this characteristic led to the discovery of all three of the hybrid plants herein described, found at Arlington Farm.

The heads of this hybrid plant and of the neighboring wheat plant are shown in Plate II, figure 2, together with two heads of Rimpau rye, the variety which may have been the pollen parent of the hybrid. These rye heads were grown in a different year and in different environment from the hybrid and the wheat. Measurements and other data on the wheat and hybrid plants are given in Table 1.

TABLE 1.—*Notes on Wheat-Rye Hybrid, Plant No. 1, Found in 1914, and on a Near-by Plant of Purple Straw Wheat, in a Plat of Which the Hybrid Was Growing.*

	Culm No.	Height.	Spikelets.	Head Length.	Spikelets with 3 Flowers.
		cm.		*cm.*	
Hybrid plant	1	154.4	25	10	16
	2	141.7	24	9	14
	3	150.7	24	9	14
Wheat	1	144.2	18	6.8	13
	2	113.5	18	6.2	11

The peduncles of the hybrid culms are pubescent and scabrous for 4 and 5 cm. below the head, while those of the wheat are entirely glabrous. The shape, nerves and keels of the glumes of the hybrid have the same relation to those of the wheat as is noted above in the case of the artificial hybrid. The color of the wheat glumes in this case, however, is light yellow, while that of the glumes of the hybrid is a slightly deeper yellow. The surface of the glumes of both the wheat and the hybrid is scabrous, with margins ciliate, diminishing upward, although the margins of the glumes of the hybrid are somewhat more finely ciliate than in the wheat. The lemmas of the hybrid also bear the same relation to those of wheat as has been noted for the lemmas of the artificial hybrid described above. The lemmas of both the wheat and the hybrid in this case, however, are glabrous, while those of the artificial hybrid and of the wheat parent are more or less pubescent. The awns of the wheat are about 1 mm. long on the lower spikelets and increase upward to about 20 mm. on the apical spikelets, while in the hybrid they increase from about 1 mm. on the lower spikelets to 25 to 40 mm. on the apical. One kernel was produced on one of the three hybrid heads. It is somewhat shrunken, light red in color, rather long in proportion to its width, and about the same width from end to end, with V-shaped crease. The kernel as a whole has little resemblance to rye, but resembles wheat very much.

Natural Wheat-Rye Hybrid No. 2.

Hybrid No. 2 was found growing in the same plat of wheat as was No. 1. The heads of the hybrid plant and two heads of a neighboring wheat plant are shown in Plate III, figure 1, together with two heads of Rimpau rye, the variety which may have been the pollen parent of the hybrid. These rye heads were from the 1911 crop. This hybrid was entirely sterile but altogether it does not vary from hybrid No. 1 in any essential character, so a detailed description is not considered necessary. In Table 2 some measurements are given, however, for the two heads of this plant and for the heads of a wheat plant growing near.

Table 2.—*Notes on Wheat-Rye Hybrid No. 2, Found in June, 1914, and on a Neighboring Plant of Purple Straw Wheat, in a Plat of Which the Hybrid Was Growing.*

	Culm.	Height.	Length of Head.	No. Spikelets.	
				Total.	3-Flowered.
		cm.	*cm.*		
Hybrid No. 2	1	142.8	9.6	25	21
	2	140.0	9.3	25	17
Wheat growing near the hybrid	1	122.6	6.6	17	9
	2	107.3	6.0	17	5
	3	112.0	5.7	17	10

The peduncle of hybrid No. 2 is sparingly pubescent from the head to about 1.5 cm. below the head. It is less pubescent than in hybrid No. 1. The peduncles of the hybrid were colored a somewhat darker purple than those of the neighboring wheat plants.

Natural Wheat-Rye Hybrid No. 3.

This hybrid was found in a plat of Dawson Golden Chaff wheat. The wheat with which this plat was sown had grown the previous year in a position not far removed from rye plants. Rye is recorded as having grown not more than 20 feet away and it is possible that a few plants may have grown closer than this. The plant consisted of a single culm, bearing a head that was fully formed but entirely sterile. This hybrid head, which is shown in Plate III, figure 2, together with a head of Dawson Golden Chaff wheat from a nearby plant and a head of Rimpau rye grown in 1911, does not differ from that of hybrid No. 1, described above, in any of the essential characters that distinguish it as a wheat-rye hybrid. Some slight differences exist, however. The head is not so compact in form; the glumes and lemmas average slightly wider, the awns on the upper

spikelets attain slightly greater length, the longest being about 50 mm., and the floral envelopes are of a somewhat deeper yellow color than those of hybrid No. 1. These differences can be attributed to the supposed difference in parentage and are in line with the expectation, as the floral envelopes of Dawson Golden Chaff are of a deep yellow or reddish color, while those of Purple Straw are almost white. The form of head also differs slightly, the outer kernels of a spikelet standing at a wider angle from each other in the former than in the latter variety, which would account for the less compact form of hybrid No. 3.

Notes are given on natural wheat-rye hybrid No. 3 in Table 3, and also on a plant of the surrounding wheat that was preserved for comparison.

TABLE 3.—*Notes on Wheat-Rye Hybrid No. 3, Found in June, 1914, and on a Neighboring Plant of Dawson Golden Chaff Wheat, in a Plat of Which the Hybrid Was Growing.*

	Culm No.	Culm Height.	Head Length.	No. of Spikelets.	Spikelets with 3 or More Flowers.
		cm.	*cm.*		
Hybrid	1	138.3	10.5	25	19
Wheat	1	128.3	7.7	20	15
	2	121.1	8.5	19	13

The peduncle was pubescent and scabrous for about 12 mm. below the head, but decreasingly so from the head downward; walls were much thickened and the cavity nearly or entirely closed for some distance below the head. The peduncle of wheat was glabrous and hollow.

NATURAL WHEAT-RYE HYBRID FROM TENNESSEE.

As stated previously, two heads were sent to the writer in June, 1914, from Brush Creek, Tenn. Both of these are entirely sterile. In general appearance they are much like the artificial hybrid described above, as the heads are long and the glumes and lemmas are pubescent. No statement was made by the sender as to the variety of wheat in which this plant was found, but the cross must have been of a rye on one of the wheats having pubescent floral envelopes. Some of the distinctive characters of the natural hybrid are given and comparison made with the artificial hybrid described above.

Head long, 16 cm.; 30 spikelets; sterile; longer than usual in wheat and with more spikelets. Density 0.534 (artificial hybrid .515).

Peduncle hairy for 2 cm. below head; scabrous near head; hollow, walls fairly thick. Agrees in these with artificial hybrid described.

Spikelets 3–5 flowered, as in wheat.

Glumes 8.5–9 mm. long; 2.2–2.7 mm. wide; oblong, ovate, pubescent, membranaceous, ciliate, keeled apex to base; beak .50–.75 mm.; shoulder rounded; nerves, about 5. Similar to the artificial wheat-rye hybrid except hardly so large, of a more oblong shape, and of slightly softer texture.

Lemmas as described for artificial wheat-rye hybrid.

Summary.

Concerning all the heads here shown, it is evident from the observations made that all the supposed hybrids are sterile with the exception of one seed produced by hybrid No. 1, and that the peduncles of all are hairy and roughened for a short distance below the heads. The artificial hybrid and the one from Tennessee have pubescent glumes and lemmas; the others, nearly smooth glumes and lemmas. Pubescence on the glumes and lemmas is dominant in the first generation over the glabrous condition, so this character in the hybrid depends on the character of the wheat parent in this regard, since rye does not have pubescent floral coverings. We know that the wheat parent of the artificial hybrid had pubescent floral coverings, and we may also conclude that the Tennessee head must have had a wheat parent with this character. The hybrids found at Arlington were growing in plats of wheats having no pubescence on the floral coverings, and therefore are nearly glabrous, as we should expect crosses on these wheats to be.

The larger number of spikelets on the heads than on those of the surrounding wheat is again evidence of rye relationship. The greater length of the heads and culms also points to the same conclusion.

The shape of glumes and lemmas, the ciliate keel of the glumes, the possession of many nerves, are all similar to the known hybrid of wheat and rye.

The heads of the hybrids from different sources differ somewhat from each other, but this can be shown to be due to differences in parentage. The characters of the wheat and rye parents are inherited in the hybrids in the same way as the characters of two different wheats would be inherited in their hybrid.

That the hybrids found were produced by the fertilization of wheat flowers with rye pollen is concluded for these reasons: (1) The plants were found growing in plats of wheat; (2) no seed has ever been secured by any plant breeder, so far as reported, by fertilizing rye flowers with wheat pollen. In the writer's own experience no less than 80 rye flowers have been pollinated with the pollen from several

different kinds of wheat and no seed has ever been secured. The reciprocal cross is, however, not readily secured. In the writer's experience again no less than 173 flowers of different kinds of wheat have been pollinated with rye pollen and only 4 seeds have been secured, these being in a single head.

Taking all these things into consideration, it seems evident that the plants found are first generation hybrids of wheat and rye, the seeds from which they grew having been produced by the natural fertilization of wheat flowers with rye pollen. In no other way can the facts be explained.

THE EFFECT OF GRINDING THE SOIL ON ITS REACTION AS DETERMINED BY THE VEITCH METHOD.[1]

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Introduction.

In the course of some recent studies of Iowa soils, it became necessary to ascertain their reaction or need of lime. Inasmuch as previous tests had been carried out by the Veitch method and comparisons had indicated it to be quite satisfactory, it was decided to use that method in this work.

It was soon noted, however, that the results which were being secured were in most cases the direct opposite of those obtained by previous tests of samples of the same soil types taken from approximately the same localities. For instance, practically all the samples from Bremer County were found to be basic in reaction, whereas previous tests of the soils of that county had shown that almost all were acid. The test had been carried out in exactly the same way in both cases. Every step in the operation and every detail in manipulation were carefully checked but no difficulties were encountered with the method. The soil samples were taken in the same way, and both lots were chosen as representative of soil types. Furthermore, they were taken by the same man, so that there was every reason to expect that the reaction of the samples would be very similar. At least it was felt that the same tendency of the soils to

[1] Contribution from the Laboratory of Soil Chemistry and Bacteriology, Iowa Agricultural Experiment Station. Received for publication June 9, 1915.

react acid or basic should have been observed with both lots of samples.

There was only one difference in the two lots of samples. The first was secured especially for acidity tests and the soils were tested in an unground condition, while the second lot was obtained in connection with the soil survey of the county and the samples were finely ground before being tested. This grinding was necessary in order to prepare the samples for the chemical analysis which was to be made. It seemed possible, therefore, that the difference indicated in the reaction of the two lots of samples might be due to the grinding.

As the Veitch method determines the lime requirement or "apparent" acidity of soils and this is largely dependent on the phenomenon of absorption, it ordinarily would be assumed that grinding a soil would increase its "apparent" acidity because of the greater surface exposed. On the other hand, investigations[2] have shown that many of the common minerals, particularly the zeolites and feldspars, when reduced to fine powder and treated with carbon-dioxid-free water give a more or less strong reaction with phenolphthalein. Furthermore, in a critical study of the method which he devised, Veitch[3] noted a development of basicity in tests which were allowed to stand longer than sixteen hours and he suggested that this might be due to the solution and hydrolyzation of neutral compounds present in the soil.

The following questions then arise: When soils are ground before being tested by the Veitch method is their lime requirement greater or less than it would be under natural field conditions? Is the absorption of the added lime-water increased sufficiently to make the "apparent" acidity of the soils greater or will the greater solution of minerals lead to a decrease in the acidity indicated by the test? And finally, should soils in a ground condition be tested by the Veitch method? Although the above questions are all of considerable interest scientifically it is with the latter that we are mainly concerned at this time.

As far as the authors are aware it has not been specified in any previous work in which the Veitch method was used whether the soil should be ground or unground when tested and it is believed therefore that the work reported here may be of value in calling attention to a possible source of error in the manipulation of the

[2] Cameron, F. K., and Bell, J. M., The Mineral Constituents of the Soil Solution, U. S. Dept. Agr., Bureau of Soils Bul. No. 30, 1905.

[3] Veitch, F. P., Jour. Amer. Chem. Soc., Vol. 26, No. 6, p. 637.

test if the condition in which the soil is tested is not distinctly specified.

Experimental.

In order to determine definitely whether grinding occasions a decrease in the "apparent" acidity of soils, four samples of soil from Bremer County were secured and each sample was thoroughly mixed and divided into four portions. The first portion was unground and unsieved, the second was put through a 20-mesh sieve, the third through a 40-mesh sieve and the fourth portion was ground to pass an 80-mesh sieve. They were then tested by the Veitch method. The results are given in Table 1.

Table 1.—*Effect of Grinding Sandy Loam Soils on "Apparent Acidity" as Determined by the Veitch Method.*

Soil. No.	Soil Type.	Condition of Soil When Tested.	Reaction.	Limestone Requirement; Pounds per 2,000,000 Pounds of Surface Soil.
14	Bremer fine sandy loam . .	Unground and unsieved	Acid	2,816
	" " " " . .	Through 20-mesh sieve[1]	Acid	2,816
	" " " " . .	Through 40-mesh sieve	Acid	2,116
	" " " " . .	Through 80-mesh sieve	Basic	. . . . .
51	Bremer coarse sandy loam	Unground and unsieved	Acid	3,520
	" " " "	Through 20-mesh sieve[2]	Acid	3,520
	" " " "	Through 40-mesh sieve	Basic	. . . . .
	" " " "	Through 80-mesh sieve	Basic	. . . . .
57	Bremer sandy loam	Unground and unsieved	Acid	5,280
	" " "	Through 20-mesh sieve[2]	Acid	3,168
	" " "	Through 40-mesh sieve	Basic	. . . . .
	" " "	Through 80-mesh sieve	Basic	. . . . .
24	Carrington sandy loam . . .	Unground and unsieved	Acid	3,168
	" " " . . .	Through 20-mesh sieve[1]	Acid	1,760
	" " " . . .	Through 40-mesh sieve	Basic	. . . . .
	" " " . . .	Through 80-mesh sieve	Basic	. . . . .

[1] Very little grinding.

[2] Considerable grinding.

All the soils showed acidity when tested in an unground condition (Table 1) and all showed a basic reaction when they were ground and put through an 80-mesh sieve before being tested. With 3 of these samples enough basicity was developed when the soils were ground to pass the 40-mesh sieve to change the reaction from acid to basic. Even the slight grinding necessary to put the soils through the 20-mesh sieve reduced the lime requirements of 2 of the soils. These results indicate clearly that grinding increases the basicity of soils and those normally having an acid reaction by the Veitch test may show a basic reaction.

In order to test the point further and also to ascertain to what extent the sand affects the development of a basic reaction when a ground sample is tested, 5 samples of the Lintonia series of soils from Muscatine County, Iowa, carrying different contents of sand and all reacting acid in the natural condition were tested in the same way as the previous soils. The results appear in Table 2.

TABLE 2.—*Effect of Grinding Sand and Sandy Loam Soils of the Lintonia Series on "Apparent Acidity" as Determined by the Veitch Method.*

Soil No.	Soil Type.	Percentage of Sand.	Condition of Soil When Tested.	Reaction.	Limestone Requirement; Pounds per 2,000,000 Pounds of Surface Soil.
32	Lintonia coarse sand	92.2	Unground and unsieved	Acid	5,280.0
	" " "		Through 20-mesh sieve[1]	Acid	4,224.0
	" " "		Through 40-mesh sieve	Basic	
	" " "		Through 80-mesh sieve	Basic	
37	Lintonia fine sand	92.0	Unground and unsieved	Acid	3,345.0
	" " "		Through 20-mesh sieve[2]	Acid	3,010.5
	" " "		Through 40-mesh sieve	Acid	1,672.5
	" " "		Through 80-mesh sieve	Acid	1,338.0
18	Lintonia sand	91.1	Unground and unsieved	Acid	2,341.5
	" "		Through 20-mesh sieve[3]	Acid	2,341.5
	" "		Through 40-mesh sieve	Acid	1,672.5
	" "		Through 80-mesh sieve	Basic	
8	Lintonia coarse sandy loam	86.2	Unground and unsieved	Acid	3,010.5
	" " " "		Through 20-mesh sieve[1]	Acid	3,010.5
	" " " "		Through 40-mesh sieve	Acid	1,338.0
	" " " "		Through 80-mesh sieve	Acid	1,338.0
42	Lintonia fine sandy loam	79.2	Unground and unsieved	Acid	5,017.5
	" " " "		Through 20-mesh sieve	Acid	5,017.5
	" " " "		Through 40-mesh sieve[2]	Acid	5,017.5
	" " " "		Through 80-mesh sieve	Acid	4,348.5

[1] Little grinding.
[2] Very little grinding.
[3] No grinding.

The coarse sand needed a little grinding to put it through the 20-mesh sieve. This reduced the lime requirement somewhat, but when ground and put through the 40-mesh sieve the reaction became basic. Very little grinding was required to put the fine sand through the 20-mesh sieve and while more was required for it to pass the 40-mesh and 80-mesh sieves the grinding was not sufficient to make the reaction basic. A gradual reduction in the lime requirement of the variously treated samples, however, was noted.

The Lintonia sand required no grinding to put it through the 20-mesh sieve and very little for the 40-mesh. The lime requirement became less where the soil was put through the 40-mesh sieve and the reaction became basic when the 80-mesh sieve was used. With

both the coarse sandy loam and the fine sandy loam, the lime requirement was changed by grinding, but the soils still tested acid even when ground to pass the 80-mesh sieve. As might be expected, the reduction of lime requirement was noted sooner in the coarse sandy loam, very little grinding being necessary to put the fine sandy loam through the 40-mesh sieve.

According to these results there seems to be a direct relationship between the sand content of the soil and the effect which grinding the sample exerts on the reaction by the Veitch test. The larger the amount of sand present and the coarser the condition in which it exists, the less grinding is required to alter the reaction of the soil according to the Veitch test. Where the percentage of sand is low the effects of grinding are small, although the influence in reducing the lime requirement of acid soils is still noticeable.

Evidently when soils are ground there is a decrease in "apparent" acidity due to the solution of minerals and this more than offsets any increase in acidity due to greater absorption. In order to test soils for their reaction by the Veitch method it is obviously necessary, therefore, that the soil be in its natural condition and unground.

Summary.

The results of these tests lead to the following conclusions:

1. When acid soils are ground before being tested by the Veitch method the acidity is reduced and frequently the reaction becomes basic.

2. The development of basicity increases with the grinding of the soil.

3. The increase in basicity is greater the greater the percentage of sand and it is greater in coarse sandy soils than in fine sands.

4. To determine the reaction of soils by the Veitch method, they should not be ground.

A COMPARATIVE STUDY OF THE EFFECT OF CUMARIN AND VANILLIN ON WHEAT GROWN IN SOIL, SAND, AND WATER CULTURES.

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(*Continued from the July–August number.*)

EXPERIMENTAL DATA.

OBJECT OF THE EXPERIMENTS.

All the laboratory work on soil toxicity dealing with introduced organic deleterious substances has been carried out in water cultures. No attempts have ever been made to determine how the toxic substances which either have been isolated or which have been thought possibly to be present in the soil would behave in actual field tests, although it could reasonably be expected that the soil through its many various agencies would greatly modify their toxic action.[27]

In the experiments conducted by the writer during the winter of 1912–13, the principal object was to obtain some data as to how substances which were found to be toxic to plants in water cultures would affect crops grown to maturity in soil, and how these effects would be modified by lime, by each individual mineral fertilizer, and by a complete fertilizer. The work was limited to two organic toxins, cumarin and vanillin. These substances were selected because they have been used in a number of experiments with water cultures in order to demonstrate the behavior of organic toxins, and because they could be easily obtained in sufficient quantities in a pure state.

Experiments with water cultures and quartz cultures were conducted parallel with the field experiments.

EXPERIMENTS WITH SOIL.

The experiments with soil were conducted in 3-gallon pots in the greenhouse. The soil used was Dunkirk clay loam from the experimental plots of the Cornell University Agricultural Experiment Station. Ten kilograms of soil were weighed out in each pot. The pots were watered as frequently as was necessary, once a week at the beginning of the experiment when there was very little transpiration and two to three times a week toward the period of maturity.

[27] Since this paper was prepared, a bulletin by Schreiner and Skinner (Harmful Effects of Aldehydes in Soils, U. S. Dept. Agr. Bul. No. 108, 1914) has appeared which gives the results of field plat tests with toxic substances.

Only distilled water was used. The moisture content of the soil at the time of watering was 30 percent on the dry basis. The pots were kept under a mulch of white quartz sand. Thirty-six wheat seeds were sown in each pot, the stand afterward being thinned to 12 plants per pot.

The toxins were added in parts per million and were figured on the basis of the highest total moisture content of the soil at the time of watering. The concentrations used were 200, 100, and 10 parts per million for cumarin, and 1,000, 500 and 10 parts per million for vanillin. The highest concentrations used were twice the killing concentrations in water cultures.

The experiments consisted of six series: (1) Without additional treatment, (2) with lime, (3) with nitrogen, (4) with phosphoric acid, (5) with potash and (6) with a complete fertilizer. Nitrogen was added as sodium nitrate, phosphoric acid as disodium phosphate, potassium as potassium chloride and lime as calcium hydroxide. Nitrogen, phosphoric acid and lime were added on the basis of 400 pounds per acre, and potassium on the basis of 200 pounds per acre. Only chemically pure materials were used. Each series consisted of fourteen pots, two for each concentration of the toxins used and two control pots. In the tables which follow, the figures reported are the averages from the duplicate pots in each case.

The toxins, the fertilizers and the lime were added in the dissolved state only. The lime was added as lime water which had been titrated against a standard acid. The addition of toxins was repeated three times, each time to the extent of a full equivalent of the total moisture.

Effect on Germination.

About three weeks after planting, new seedlings ceased to appear above ground. Before thinning, the seedlings were counted in order to see whether the different treatments had any effect on the germinating power of the seeds. The percentages of germination and the relative germination as compared with the germination in the control pots in each series are given in Table 2.

The only conclusion which would seem to be justified from this table is that none of the different treatments had any effect on germination. The percentages are very irregular, the differences between the duplicates being larger than between the individual treatments. The variations seem to be mere fluctuations and seem to be due to general conditions affecting germination, as heredity and general environmental factors, and not to any single factor arising from a particular treatment.

TABLE 2.—*Effect of Different Concentrations of Cumarin and Vanillin on the Germination of Wheat, as Shown by the Percentage of Germination and the Ratio of Each to the Control.*

Toxin.	P.p.m.	No Treatment.		CaO.		N.		P_2O_5.		K_2O.		Complete Fertilizer.	
		%	Ratio.	%	Ratio.	%	Ratio.	%	Ratio.	%	Ratio.	%	Ratio.
Cumarin . .	200	53	76.8	67	80.7	81	117.4	64	79	69	107.8	69	88.5
" . .	100	64	92.8	86	103.6	78	113	81	100	67	104.7	69	88.5
" . .	10	75	109	75	90.4	75	108.7	67	82.7	69	107.8	75	96.2
Control . . .	. . . . .	69	100	83	100	69	100	81	100	64	100	78	100
Vanillin . . .	1,000	67	97.1	83	100	69	100	72	88.9	75	117.2	86	110.3
" . . .	500	61	88.4	83	100	72	104.3	72	88.9	75	117.2	78	100
" . . .	10	75	109	72	86.7	67	97.1	78	96.3	78	121.9	81	103.8

Effect on Yield.

The plants in the pots were grown to maturity. Observations taken during the period of growth did not lead to any definite conclusions. It seemed from time to time that the stand in the cumarin pots of the two higher concentrations was inferior to that of the control pots in some of the series, especially in the nonfertilized and in the limed series. However, no abnormalities in the appearance of the plants in these pots were observed. They looked normally green and as healthy as the plants in the other pots.

In Table 3 the weights of the water-free substance for the grain and straw and the total yield are given. The table gives the average weights for the duplicates and the proportional values of the averages with reference to the control pots in each series, the yields of which are taken as 100.

In the weights of the grain shown in Table 3 there is a certain regularity in the nonfertilized and in the limed series. The highest concentrations give inferior yields; the lower concentrations give yields either equal to or slightly higher than the control pots. In the nitrogen series the regularity is preserved with reference to the cumarin pots, while in the vanillin pots the yields are arranged in the reverse order, the differences, however, being very small. The phosphoric acid series preserves the regularity except for the pots which received the highest concentration of vanillin. These latter gave an abnormally high yield as compared with the remaining pots of the same series. The potassium series varies very little and not in the expected direction. The complete fertilizer series is very regular, the variations being gradual and pronounced as in the first two series.

The weights of the straw are on the whole less regular than those of the grain. The nonfertilized series follows the regular order

completely. The limed series also varies in the expected direction except in the case of the second concentration of cumarin. The remaining series do not show any regularity in their variations.

TABLE 3.—*Weights (Water-free Substance) of Grain, Straw and Total Weight Obtained from Pot Cultures of Wheat Variously Fertilized and Treated with Different Concentrations of Cumarin and Vanillin, with the Ratio of Each to the Control Taken as 100.*

WEIGHTS OF GRAIN.

Toxin.	P.p.m.	No Treatment.		CaO.		N.		P_2O_5.		K_2O.		Complete Fertilizer.	
		Weight.	Ratio.	Weight.	Ratio.	Weight.	Ratio.	Weight.	Ratio.	Weight.	Ratio.	Weight.	Ratio.
		Gm.		*Gm.*		*Gm.*		*Gm.*		*Gm.*		*Gm.*	
Cumarin . .	200	4.21	64.8	6.12	74.5	14.9	85.1	4.96	80.5	6.34	100.8	10.9	63
" . .	100	5.08	78.1	7.55	92.0	18.3	104.6	6.42	104.2	6.61	105.1	13.8	79.8
" . .	10	6.75	103.9	7.69	93.7	18.9	108	7.16	116.2	6.58	104.6	16.3	94.2
Control . . .	. . . . .	6.50	100	8.21	100	17.5	100	6.16	100	6.29	100	17.3	100
Vanillin . . .	1,000	5.79	89.1	5.66	68.9	16.8	96	9.96	161	6.93	110.2	15.2	87.9
" . . .	500	6.72	103.4	6.48	78.9	16.3	93.1	6.14	99.7	6.37	101.3	15	86.7
" . . .	10	7.47	114.9	8.28	100.9	16.1	92	6.55	106.3	6.58	104.6	15.6	90.2

WEIGHTS OF STRAW.

Cumarin . .	200	23.4	85.4	25.9	92.5	54.7	102	25.7	101.6	22.4	104.7	40.0	95.2
" . .	100	25.9	94.5	29.5	105.3	55.7	103.9	27.6	109.1	21.1	98.6	45.9	109.3
" . .	10	28	102.2	27.5	98.2	53.2	99.3	27.4	108.3	24.5	114.5	44.7	106.4
Control . . .	. . . . .	27.4	100	28	100	53.6	100	25.3	100	21.4	100	42	100
Vanillin . . .	1,000	24.6	89.8	22.9	81.8	48.9	91.2	34.8	137.6	24.9	116.4	43.9	104.5
" . . .	500	27.1	98.9	24.7	88.2	50.3	93.8	24.2	95.6	20.3	94.9	47.5	113.1
" . . .	10	28	102.2	28.5	101.8	52.5	97.9	23.2	91.7	19	88.8	46.4	110.5

TOTAL WEIGHTS.

Cumarin . .	200	27.6	81.4	32.1	88.6	69.7	96.7	30.7	97.4	28.7	103.6	50.8	85.8
" . .	100	31	91.4	37.1	102.5	74.1	102.8	34	107.9	28.7	103.6	54.8	92.2
" . .	10	34.8	102.7	35.2	97.2	72.1	100	34.5	109.5	31.1	112.3	61	102.7
Control . . .	. . . . .	33.9	100	36.2	100	72.1	100	31.5	100	27.7	100	59.4	100
Vanillin . . .	1,000	30.4	89.7	28.6	79	65.7	91.1	44.7	141.9	31.8	114.8	59.1	99.5
" . . .	500	33.8	99.7	31.2	86.2	66.6	92.4	30.4	96.5	26.7	96.4	62.5	105.2
" . . .	10	35.4	104.4	36.5	100.8	68.7	95.3	29.7	94.3	25.5	92.1	62	104.3

The total yields of the grain and straw naturally occupy a place between the weights of each separately with reference to the tendency to show a regular trend in any direction. The nonfertilized and the limed series again prove to be the most regular. The complete fertilizer series comes next, being quite regular in the cumarin pots. The nitrogen series shows a tendency to regularity, being more regular in the vanillin half. The potassium series again proved to be the least regular. On the whole, the variations in the total yield are not very sharp.

The general impression produced by examination of Table 3 would be that the highest concentrations of the cumarin and vanillin caused a slight depression in yield, especially in the yield of grain, and that the depression is more pronounced and more regular in the nonfertilized, in the limed, and in the complete fertilizer series. The addition of the individual fertilizers seemed to have a disturbing influence on the tendency to follow the regular effects of the toxins used. No conclusion can be drawn as to whether it was accidental (which is not improbable in view of the fact that the variations in general were not very sharp) or whether it was due to the influence of the fertilizer. Neither is it possible to draw any conclusions with reference to the effects of the individual fertilizers in the absence of distinct variations since there was only one series for each fertilizer. The complete fertilizer did not seem to modify the effects of the cumarin and vanillin.

Effect on the Nitrogen Content.

The nitrogen content may serve sometimes as an indication of the presence of certain factors which influence the general yield of a crop. If a depression in yield is caused by some accidental factor, the tendency is in the direction of a relatively higher nitrogen content. The reason for this phenomenon might be due either to the fact that the interfering factor does not affect the production of nitrates in the soil, or that it does not affect the assimilative power of the plant for nitrogen. It was thought, therefore, that the nitrogen content of the crops might throw some light on the nature of the influence exerted by the cumarin and vanillin treatment. Table 4 gives the percentages of nitrogen in the grain and in the straw and the ratios of the different treatments to the control, taking the percentage of nitrogen in the controls as 100.

Examining these tables, we find that the percentages of nitrogen in the straw fluctuate too irregularly to allow of any generalizations. We find, for instance, that in the nonfertilized and the limed series, which proved to be the most regular ones with reference to the weight of water-free substance the highest concentrations of cumarin and vanillin gave approximately the same percentages as the controls. In the remaining series, the concentration of 200 parts per million of cumarin gave somewhat higher percentages than the controls. The other concentrations of cumarin, as well as all the concentrations of vanillin, do not follow any regular order.

TABLE 4.—*Nitrogen Content of Wheat Grain and of Straw Grown in Pot Cultures Variously Fertilized and Treated with Different Concentrations of Vanillin and Cumarin, with the Ratio of Each to the Control Taken as 100.*

WHEAT GRAIN.

Toxin.	P.p.m.	No Treatment.		CaO.		N.		P_2O_5.		K_2O.		Complete Fertilizer.	
		Nitrogen.	Ratio.	Nitrogen.	Ratio.	Nitrogen.	Ratio.	Nitrogen.	Ratio.	Nitrogen.	Ratio.	Nitrogen.	Ratio.
		%		%		%		%		%		%	
Cumarin . .	200	1.72	107.5	1.91	107.9	2.27	113.5	2.15	114.4	2.06	106.7	2.15	108.6
" . .	100	1.75	109.4	1.76	99.4	2.01	100.5	2.00	106.4	1.95	101	2.09	105.5
" . .	10	1.81	113.1	1.58	89.3	2.07	103.5	1.96	104.3	1.89	97.9	2.10	106.1
Control . . .	.....	1.60	100	1.77	100	2.00	100	1.88	100	1.93	100	1.98	100
Vanillin . . .	1,000	1.76	110	1.89	106.8	1.89	94.5	1.97	104.8	1.89	97.9	2.03	102.5
" . . .	500	1.82	113.7	1.68	94.9	2.01	100.5	1.98	105.3	1.93	100	2.06	104
" . . .	10	1.68	105	1.81	102.3	2.04	102	1.93	102.7	1.97	102.1	2.13	107.6

WHEAT STRAW.

Cumarin . .	200	0.39	102.6	0.33	103.1	0.46	135.3	0.45	118.4	0.39	114.7	0.35	112.9
" . .	100	.31	81.6	.34	106.2	.41	120.6	.33	86.8	.32	94.1	.35	112.9
" . .	10	.31	81.6	.38	118.8	.38	111.8	.34	89.5	.35	102.9	.35	112.9
Control . . .	.....	.38	100	.32	100	.34	100	.38	100	.34	100	.31	100
Vanillin . . .	1,000	.42	110.5	.32	100	.36	105.9	.36	94.7	.30	88.2	.29	93.6
" . . .	500	.41	107.9	.30	93.7	.40	117.6	.36	94.7	.32	94.1	.39	125.8
" . . .	10	.30	78.9	.33	103.1	.43	126.5	.39	102.6	.37	108.8	.42	135.5

The percentages of nitrogen in the grain exhibit a regularly borne out consistency with reference to the concentration of 200 parts per million of cumarin, as they are consistently higher than those of the controls in all the series. With reference to the remaining concentrations of cumarin and those of vanillin, the consistency varies with the series, and does not, on the whole, allow any generalizations as in the case of the straw.

The depression in yield of grain, which was most pronounced in the case of the concentration of 200 parts per million of cumarin, would seem to be accompanied by a relatively higher nitrogen content which is characteristic of the presence of some factor interfering with plant growth. The question is whether the effect of the interfering factor was directly on the plant, causing some morphological derangement or interfering with its physiological functions, or whether the effect was on the medium in which it grew.

The appearance of the plants in the pots to which the toxic substance had been added was perfectly normal, as stated above. The roots were found to permeate the soil in every direction and did not show any inferior development as compared with the controls. The

depression in yield was not evidently due to lack of nitrogen, but the possibility of its being due to a relative deficiency in some of the other available elements of plant food, actual or physiological, caused by the interfering factor, is not excluded. It is also possible that the interfering factor affected the physical and biological conditions of the soil.

Effect on Nitrates.

In order to obtain some idea of the effects of the toxins used on the biological activity of the soil, the soil in the pots was analyzed for nitrates.

The pots could not be handled immediately after the crops were harvested, but were held at a low moisture content and were analyzed, a complete series at a time, so that each series could be compared only with its own control pots. During the sampling, the soil was removed from the pots, pulverized, and thoroughly mixed. After the first sampling, the soil was returned to the pots, kept at about 25 percent of moisture for a time, and analyzed again. This was analogous to incubation, as the pots were kept in the greenhouse and were all subject to the same variations in temperature, which (the weather at that time of the year being constant) were limited only to the difference of the day and night temperature. Again, one series was handled at a time, so that each series was incubated for a different length of time.

The nitrates in parts per million are given in Tables 5 and 6. In Table 5 the averages of the duplicate pots are compared with the averages of the control pots in each series, the latter being taken as 100. In Table 6 the increase in nitrates for the period of incubation was calculated and the average increase of the duplicate pots is compared with the average increase of the control pots taken as 100.

TABLE 5.—*Nitrates in Pot Cultures Variously Fertilized and Treated with Different Concentrations of Cumarin and Vanillin, as Determined before Incubation, with the Ratio of Each to the Control Taken as 100.*

Toxin.	P.p.m.	No Treatment.		CaO.		N.		P_2O_5.		K_2O.		Complete Fertilizer.	
		NO_3, P.p.m.	Ratio.	NO_3, P.p.m.	Ratio.	NO_3, P.p.m.	Ratio.	NO_3, P.p.m.	Ratio.	NO_3, P.p.m.	Ratio.	NO_3, P.p.m.	Ratio.
Cumarin . .	200	15.6	82.5	33.5	97.1	20.1	57.8	37.3	119.2	36.6	106.1	52.2	64.3
" . .	100	14.2	75.1	31.8	92.2	22.9	65.9	44.8	143.1	36.6	106.1	52.8	65
" . . .	10	16	84.7	32.3	93.6	31.6	90.8	36.5	116.6	36.7	106.4	51.6	63.5
Control . . .	. . . . .	18.9	100	34.5	100	34.8	100	31.3	100	34.5	100	81.2	100
Vanillin . . .	1,000	9.4	49.7	19.8	57.4	23.2	66.7	60.6	193.6	31	89.9	52.2	64.3
" . . .	500	11.2	59.3	24.7	71.6	38.3	110	35.6	113.7	33.7	97.7	43.6	53.7
" . . .	10	15.2	80.4	26	75.4	29.9	85.9	32.5	103.8	21.5	62.3	55.9	68.8

TABLE 6.—*Increase of Nitrates after Incubation from Pot Cultures Variously Fertilized and Treated with Different Concentrations of Cumarin and Vanillin, with the Ratio to the Control Taken as 100.*

Toxin.	P.p.m.	No Treatment.		CaO.		N.		P_2O_5.		K_2O.		Comp. Fert.
		Incr., P.p.m.	Ratio.	Incr., P.p.m.	Ratio.	Incr., P.p.m.	Ratio.	Incr., P.p.m.	Ratio.	Incr., P.p.m.	Ratio.	Incr., P.p.m.
Cumarin..	200	42.9	129.6	23.9	85.4	21.6	73	29.9	198	14.6	69.2	17.4
" ..	100	41.7	126	23.5	83.9	26.4	89.2	31	208.3	9.5	48.1	9.9
" ..	10	34.3	103.6	27.5	98.2	33.7	113.8	29.7	196.7	21.5	101.9	16.3
Control...	.....	33.1	100	28	100	29.6	100	15.1	100	21.1	100	Loss
Vanillin...	1,000	24.3	73.4	19.5	69.6	31.9	107.8	27.5	182.1	14.9	70.6	14.3
" ...	500	28.2	84.6	19.1	68.2	22.2	75	23.4	155	11.2	53.1	15.5
" ...	10	51.7	156.2	24.6	87.9	26.5	89.5	22.9	151.6	9.9	46.9	25.4

As is seen in Table 5, the nitrates in four series are consistently higher in the control pots than in the pots to which the toxins had been added. The phosphoric acid series goes in the opposite direction and the potassium series is only partially consistent.

Table 6, presenting the data for the incubation period, shows that in the toxin-treated pots of the lime, the nitrogen, and the potassium series the increase in nitrates is lower than in the control pots. The phosphoric acid goes the other way as in the period preceding incubation. In the complete fertilizer series, the control pots showed a reduction in nitrates instead of an increase, so that there is no standard of comparison. In the nonfertilized series, the increase in the control pots was larger than in the vanillin pots, but smaller than in the cumarin pots. This might have been due to the fact that this series was incubated for the longest period of time and the cumarin was completely decomposed. As will be seen later, there are indications that the effects of cumarin are more subject to amendment through decomposition by the soil agencies than are the effects of vanillin.

The general impression produced by the figures representing the results of the analysis for nitrates, would be that the addition of the toxins used seemed to interfere with nitrification.

The behavior of the cumarin and the vanillin with reference to their effects on nitrification would seem to be analogous to the behavior of soluble organic matter in general. König, Hasenbäumer and Glenk[28] found that the addition of glucose invariably inhibited nitrification. The inhibiting effect of soluble organic matter on

[28] Konig, J., Hasenbaumer, J., and Glenk, K., Uber die Anwedung der Dyalise, etc., Landw. Vers. Stat., 79–80 (1913), p. 491–534.

nitrification might be either directly on the nitrifying organism or on the soil factors affecting their activity. Another possibility is that the soluble organic matter stimulates the growth of other bacteria which compete with the nitrifying organisms for the means of subsistence. König and his associates invariably found higher bacterial numbers as a result of the addition of glucose.

Effect on Conductivity.

The same authors found that the addition of glucose reduced the conductivity of the soil. The explanation suggested by them is that the glucose acts protectively toward the electrolytes of the soil, thus interfering with the movements of the ions. In discussing the depression in yield, which under certain conditions is produced by the addition of sugar, the authors suggest that the electrical conductivity or the movement of the ions is in itself a factor in soil fertility. It was, therefore, interesting to see how the cumarin and vanillin, which produced a slight depression in yield practically similar to that produced by the addition of glucose, would affect the conductivity of the soil in the experimental pots.

Fifty grams of soil were thoroughly mixed with 50 percent of distilled water on the dry basis, and the resistance measured by a Wheatstone bridge. Tables 7 and 8 show the resistance in ohms calculated at 60° F. before and after incubation.

The results are not entirely consistent, but nevertheless a general inspection of the tables gives the impression that the soil in the pots to which cumarin and vanillin had been added showed a somewhat higher conductivity as compared with the control pots, for the period following incubation.

TABLE 7.—*Effect on Conductivity of Various Fertilizers and Treatments with Different Concentrations of Cumarin and Vanillin, as Shown by the Resistance in Ohms Calculated at 60° F. before Incubation, with the Ratio of Each to the Control.*

Toxin.	P.p.m.	No Treatment.		CaO.		N.		P_2O_5.		K_2O.		Complete Fertilizer.	
		Resistance.	Ratio.	Resistance.	Ratio.	Resistance.	Ratio.	Resistance.	Ratio.	Resistance.	Ratio.	Resistance.	Ratio.
Cumarin	200	2,174	104.2	1,970	96.7	2,137	112.7	1,779	82.3	1,609	115.2	1,774	99.7
"	100	2,229	106.8	2,003	99.6	2,250	118.7	1,720	79.6	1,700	121.7	1,681	94.5
"	10	2,369	113.5	2,181	107.1	1,996	105.3	1,951	90.3	1,701	121.8	1,702	95.7
Control	.....	2,087	100	2,038	100	1,896	100	2,161	100	1,397	100	1,779	100
Vanillin	1,000	2,416	115.8	2,324	114	1,875	98.9	1,711	79.1	1,579	113	1,682	94.5
"	500	2,195	105.2	2,446	120.1	1,550	81.8	1,981	91.7	1,337	95.7	1,714	96.3
"	10	1,979	94.8	2,484	121.9	1,675	88.3	1,951	90.3	1,944	139.1	1,423	80

TABLE 8.—*Effect on Conductivity of Various Fertilizers and Treatments with Different Concentrations of Cumarin and Vanillin, as Shown by the Resistance in Ohms after Incubation Calculated at 60° F., with the Ratio of Each to the Control.*

Toxin.	P.p.m.	No Treatment.		CaO.		N.		P_2O_5.		K_2O.		Complete Fertilizer.	
		Resistance.	Ratio.	Resistance.	Ratio.	Resistance.	Ratio.	Resistance.	Ratio.	Resistance.	Ratio.	Resistance.	Ratio.
Cumarin	200	1,680	90	1,515	93.2	1,550	110	1,499	86.8	1,356	102	1,642	103.2
"	100	1,867	100	1,580	97	1,700	120	1,430	82.8	1,455	109	1,488	93.5
"	10	1,929	103	1,633	105	1,487	105	1,653	95.7	1,381	103.8	1,540	96.8
Control		1,867	100	1,625	100	1,412	100	1,727	100	1,330	100	1,591	100
Vanillin	1,000	1,736	93	1,817	112	1,475	104.5	1,430	82.8	1,307	98.3	1,540	96.8
"	500	1,744	95	1,732	107	1,525	108	1,628	94.3	1,233	92.7	1,565	98.4
"	10	1,649	88.3	1,694	104	1,600	113	1,801	104.3	1,529	115	1,283	80.6

This, however, is not directly contradictory to the results obtained by König and his associates, since we have introduced the crop factor, while their results were obtained without growing any crop in the soil experimented with, and since the measurements in these experiments were made a comparatively much longer time after the organic substances were added.

The soil in the cumarin and the vanillin pots seemed to show after incubation a higher conductivity in spite of the fact that the respective treatments apparently reduced their nitrate content. It is possible that the plants withdrew from the soil, in the presence of the toxins used, less of the other electrolytes. This might have been due either to the fact that the toxins interfered directly with the absorption of these electrolytes by the plant, or that they stimulated the growth of microorganisms which held the electrolytes tied up in their tissues at the time of active plant growth.

That organic substances which prove to be toxic to higher plants in water cultures may be favorable to the growth of microorganisms, was shown by the fact that a solution containing 200 parts per million of cumarin showed to the naked eye an abundant growth of molds and fungi when allowed to stand for some time. The same was true with dihydroxystearic acid which had been isolated from a soil in Tompkins County, New York.

It is remarkable that König and his associates failed to see the possibility of any connection between the higher bacterial numbers resulting from the addition of sugar and the other phenomena resulting from the same treatment, as depression in yield, lowering of conductivity, and the reduction in the nitrate content. Such a con-

nection would not be improbable according to the works of Stoklasa,[29] Severin[30] and Duschetschkin.[31]

Experiments with Water Cultures.

Effect on Germination.

Wheat seeds were allowed to germinate on filter paper in petri dishes. Fifty seeds were placed in each dish to which 15 c.c. of solutions of the respective concentrations of cumarin and vanillin were added. Fifteen c.c. of distilled water were added to the control petri dishes. The test was run in duplicate. Observations were taken after six and ten days. Table 9 shows the results obtained after six days.

Table 9.—*Effect of Different Concentrations of Cumarin and Vanillin on the Germination of Wheat in Water Cultures.*

Toxin.	P.p.m.	Average Germination.	Percent.	Description of Seedlings.
Cumarin....	200	0	0	
"	100	.....	.....	
"	10	22	44	Normally developed seedlings.
Control.....	.....	22	44	Better than in the previous case.
Vanillin.....	1,000	5	10	Very weak.
"	500	9	18	Better than in previous case. Some poor, but normal seedlings.
"	10	26	52	Vigorous.

Most of the seeds which are recorded as not germinated in reality made slight efforts to germinate, but evidently the seedlings were killed in the earliest stage of embryonic development.

The second observations did not reveal any changes with reference to the cumarin treatment, except that the seeds were all overgrown with molds and fungi. The vanillin petri dishes, however, showed considerable improvement, especially those which received 500 parts per million. In these the percentage of germination and the percentage of normally developed seedlings increased considerably (germination, 32 percent; normally developed seedlings, 26 percent).

It is thus seen that cumarin had a more injurious effect on germination than vanillin. It is also seen that the deleterious effect of

[29] Stoklasa, Julius, Biochemischer Kreislauf des Phosphat-ions im Boden, Centbl. Bakt., 29, (II), 1911, p. 385–519.

[30] Severin, S. A., Changes of Phosphoric Acid in the Soil, etc., Centbl. Bakt., 28, (II), 1910, p. 561–580.

[31] Duschetschkin, A., Biological Absorption of Phosphoric Acid, Jour. Exp. Agr. (Russia), 12, p. 650–666.

the vanillin decreased with the time, in spite of the fact that the respective solutions became more concentrated due to evaporation.

Effect of Cumarin on the Growth of Seedlings Grown in Nutrient Solution of Various Concentrations.

Tumblers of 250 c.c. capacity were used. They were covered with paraffined paper in which small holes were made with a pointed glass rod. The roots of germinated seedlings were carefully introduced into the tumblers filled with nutrient solution, through the holes of the paper covers, so that the attached seeds remained rested on the upper side of the paper. Four seedlings were planted in each tumbler.

The nutrient solution used was of the following composition:

Calcium nitrate	2.7	gm. per liter.
Monopotassium phosphate	1.5	gm. per liter.
Magnesium sulphate	0.6	gm. per liter.
Potassium chloride	0.75	gm. per liter.
Ferric sulphate	0.05	gm. per liter.

This nutrient solution was used in full strength and also diluted 3 and 10 times respectively. The concentrations of cumarin were 200, 100, and 10 parts per million. The experiment was run in triplicate. The seedlings were grown for two weeks. The dry weights determined collectively for each set of triplicates are given in Table 10.

TABLE 10.—*Dry Weights of Wheat Seedlings Grown for Two Weeks in Different Concentrations of Cumarin.*

Cumarin.	Concentration of Nutrient Solution.	Dry Weights.	Relative Weights.
p.p.m.		*Grams.*	
200	1 : 10	Killed after 7 days	
100	1 : 10	" " " "	
10	1 : 10	0.2562	82
Control	1 : 10	.3120	100
200	1 : 3	Killed after 7 days	
100	1 : 3	" " " "	
10	1 : 3	.5160	76
Control	1 : 3	.6820	100
200	1 : 1	Killed after 7 days	
100	1 : 1	" " " "	
10	1 : 1	.4630	60
Control	1 : 1	.7696	100

As seen from Table 10, the depressing effect of 10 parts per million of cumarin is greater in the nutrient solution of the higher concentration. It is evident, however, that the increased nutrient content did not increase the deleterious action of the toxin, since the absolute yields are higher in the higher concentrations of the nutrient solu-

tion. The deleterious effects of the toxin were more pronounced in the case of the higher concentrations of the nutrient solution, probably because the yields in general were higher with these concentrations.

It is clear, however, that the higher concentrations of the nutrient did not reduce the toxicity of the cumarin. The ameliorating effect of phosphoric acid on cumarin reported by Schreiner and Skinner[32] is evidently not antagonistic in character, nor is it evidently due to the fact that phosphoric acid increases the resisting power of the plant to the action of the toxin, since an increased concentration of this substance did not have the same effect in a balanced solution.

It is possible that the results obtained by Schreiner and Skinner were due to the residual effect of the source of phosphoric acid after the latter was used. It is also possible that the presence of cumarin does not interfere with the absorption of phosphoric acid, while it does interfere with the absorption of the other nutrient elements, and therefore the difference in yield between the controls and the cumarin cultures are more pronounced in the case of distilled water and a balanced nutrient solution than in the case of a solution of phosphoric acid.

Effects of Small Quantities of Soil on the Behavior of Cumarin and Vanillin.

The methods used were in the main similar to those in the previous experiment. The nutrient solution used was the one given above, diluted four times. The experiment was run in triplicate, and consisted of two series which differed only in the fact that each tumbler of the second series received 2 grams of field soil. Both series were run simultaneously, and under exactly the same conditions. The

TABLE II.—*Dry Weights of Wheat Seedlings Grown for Two Weeks in Water Cultures Containing Different Concentrations of Cumarin and Vanillin, with and without the Addition of Small Quantities of Soil.*

Toxin.	Concentration.	Solution Without Soil.		Solution Plus 2 Grams of Soil.	
		Average Weight.	Ratio.	Average Weight.	Ratio.
	p.p.m.	*Grams.*		*Grams.*	
Cumarin	200	Killed after 7 days		0.1625	99
"	100	" " " "		.1708	104
"	10	0.1473	77	.1874	115
Control		.1901	100	.1631	100
Vanillin	1,000	Killed after 7 days		Killed after 7 days	
"	500	" " " "		" " " "	
"	10	.1817	92	.1552	95

[32] Schreiner, Oswald, and Skinner, J. J., Organic Compounds and Fertilizer Action, U. S. Dept. of Agr., Bur. Soils Bul. No. 77. 1911.

seedlings were grown for two weeks. The average weights of the water-free substance from the triplicate cultures are given in Table 11.

As seen from Table 11, the toxic effects of the cumarin were completely destroyed by the addition of a very small quantity of soil. As the table shows, the cumarin tumblers of the second series gave higher yields than the controls, but it is safer to ignore this fact since we can not base too much on small differences in yields obtained from seedlings grown for two weeks. It is clear, however, that the toxic effects of the cumarin were entirely overcome. This was also shown by the appearance of the seedlings, especially by the appearance of the roots, which were perfectly healthy and very much branched in the concentration of 200 parts per million of cumarin. The comparison with the similarly treated cultures which had not received any soil is so striking that the ameliorating effect of the soil on the action of cumarin under the conditions of this experiment is beyond any doubt. On the behavior of the seedlings in the vanillin solutions, on the other hand, the addition of soil did not have any effect whatsoever.

The effect produced by the soil in the case of cumarin was probably due not to adsorption, since the quantity of soil was so small, but to decomposition. The difference in the effects of the soil on cumarin and vanillin may be due either to the fact that vanillin is not as readily decomposed by the soil organisms as cumarin, or to the fact that the products of decomposition of vanillin are just as toxic as vanillin itself, while the decomposition products of cumarin are not toxic.

This experiment would suggest that the depressing effect of cumarin on the yields in the experiments with soil might be due to different causes than those operative in water cultures.

Experiment with Quartz Cultures.

The experiment was carried out in half-gallon pots. White quartz sand thoroughly washed with hydrochloric acid was used. Two kilograms of quartz were used per pot. The nutrient solution given above in which enough cumarin and vanillin were dissolved to make up the usual respective concentrations, was added to each pot to the extent of 25 percent of the weight of the quartz. The pots were kept at 25 percent of moisture, and were watered with distilled water. Nutrient solution was added from time to time. The addition of the toxins when repeated was in solutions of the respective concentrations and in equivalents of the total moisture. Sixteen wheat seeds were planted in each pot. The germinated seedlings were thinned out to 5 per pot. The experiment was run in duplicate.

Effects on Germination.

After the seedlings ceased to appear above ground, they were counted, and the percentage of germination and the relative values, taking the controls as 100, were calculated. The results are given in Table 12.

TABLE 12.—*Effect of Different Concentrations of Cumarin and Vanillin on the Germination of Wheat in Quartz Cultures.*

Toxin.	Concentration.	Average Germination.	Percentage.	Ratio to Control.
	p.p.m.			
Cumarin	200	None	.....	.....
"	100	None	.....	.....
"	10	11	69	92
Control	.....	12	75	100
Vanillin	1,000	13	81	108
"	500	10	62	84
"	10	14	87	116

As seen from Table 12, cumarin had the same effects on germination in quartz as in a liquid medium. The seeds in the pots of the two highest concentrations, when dug out, had the same appearance as in the petri dishes—slightly swelled and having made a very slight effort to germinate.

Vanillin did not have any effect at all on germination in quartz cultures. The higher results than in the control pots as well as the lower results obtained in these cultures are to be regarded as mere fluctuations.

Effect on Growth.

After the thinned-out seedlings had been grown for about seven weeks, the tops were harvested and the weights of the water-free substance determined. The results are given in Table 13.

TABLE 13.—*Dry Weights of Wheat Seedlings Grown in Quartz Cultures Treated with Different Concentrations of Cumarin and Vanillin.*

Toxin.	Concentration.	Number of Equivalents Added.	Average Weight.	Ratio to Control.
	p.p.m.		*Grams.*	
Cumarin	200	1	Did not come up above quartz	
"	100	1	Did not come up above quartz	
"	10	2	1.6	94
Control	.....	.....	1.7	100
Vanillin	1,000	3	1.25	74
"	500	3	1.65	97
"	10	3	1.60	94

As seen from Table 13, the cumarin behaved in quartz cultures in the same way as in water cultures without the addition of soil. The vanillin behaved approximately as in the soil.

General Discussion.

Since vanillin behaved the same way in quartz sand with a comparatively low adsorptive power as in a clay soil with a comparatively high adsorptive power, the ameliorating effects of the quartz and of the soil on vanillin were probably not due to adsorption. Since, however, the soil organisms added to the water cultures with the small quantities of soil did not have any effect on the action of vanillin, the ameliorating effect of soil and quartz on this toxin was probably not due to decomposition. In all probability, vanillin is only toxic when applied in a liquid medium which envelops the roots completely in a continuous layer. This would seem to be borne out by the experiment on the effects of cumarin and vanillin on germination in a liquid medium; on longer standing the inhibiting effect of vanillin on germination decreased, in spite of the fact that the solution became more concentrated, due to evaporation.

The case is entirely different with reference to cumarin. A small quantity of soil added to water cultures containing 200 parts per million of cumarin, which is double the killing concentration, completely destroyed the injurious effects of this toxin. The distribution of the toxic solution in films on the surface of the quartz grains did not have any ameliorating effect at all on the action of cumarin. Evidently the ameliorating effect of the soil on this toxin was due to its decomposing power. Adsorption is in all probability excluded, since the small quantities of soil added to the water cultures could not have adsorbed the comparatively large quantities of the toxin in the higher concentrations. Evidently, the ameliorating effect of the soil on cumarin and vanillin demonstrated in the experiments with soil was due to different causes.

The experiments did not show clearly that the depressing effect of cumarin and vanillin on the yield of the crops grown in soil, which was more pronounced with reference to the yield of grain, was due to the same causes which are operative in water cultures. On the other hand, there are some indications that the effect of the toxins is due to different causes in the soil than in water cultures. The appearance of the crops in the pots which received the highest concentrations of the toxins was perfectly healthy. No inhibiting effect on the growth of the roots has been observed. A small quantity of soil added to the water cultures which contained cumarin entirely

destroyed its toxic effects. All these considerations would tend to suggest that the depression in yield observed was not a case of toxicity, which implies a certain morphological derangement or certain changes in the composition and constitution of the plant substance which interfere with the normal physiological functions of the plant.

Depressions in yields were obtained with glucose, which substance one would hardly consider as a toxin.[33]

The depressing effects of cumarin and vanillin on the crops grown in soil might be due to the general effect of soluble, non-nutrient organic matter.

Soluble organic matter may affect the microflora of the soil, stimulating the growth of harmful organisms or the growth of microorganisms in general which would tend to tie up available plant food, or inhibiting the growth of useful bacteria. Thus, the results of these experiments would tend to show that the highest concentrations of cumarin and vanillin had a depressing effect on nitrification.

The presence of soluble organic matter may affect to a certain extent the physical condition of the soil, forming protective films on the soil particles and thus interfering with granulation.

Soluble organic matter which is not used by the plant may interfere, as a foreign substance present in the soil solution, with the absorption by the plant of the necessary elements of plant food.

It might be added that these experiments were conducted under conditions which entirely excluded drainage, and that the frequent watering of the pots tended to compact the soil very much. It is possible that under proper conditions of drainage and cultivation, the results would be different.

On the whole, it might be said that these experiments would hardly lend much support to the assumption that the presence in the soil of organic substances toxic in water cultures is a factor of considerable importance under field conditions, when the other factors of plant growth are normally good.

Summary.

1. The evidence offered in favor of the theory of soil toxicity is not sufficient to establish the fact that the roots of higher plants excrete substances harmful to themselves or to other plants. Neither is the evidence sufficient to establish the presence in the soil of organic substances harmful to plants under normal field conditions.

[33] König, Hasenbäumer, und Glenk, l. c.

2. The concentrations of 600 parts per million of cumarin and of 3,000 parts per million of vanillin, figured on the basis of the total moisture content of the soil, depressed to some extent the yield of wheat grown to maturity in pots. There are indications, however, that the effect was rather on the soil than on the plant.

3. The addition of small quantities of soil to water cultures entirely destroyed the toxic effects of cumarin, while it did not affect the action of vanillin. It is possible that vanillin is less readily decomposed by the microorganisms of the soil than cumarin, or that the decomposition products of vanillin are as toxic in water cultures as vanillin itself.

4. In quartz cultures, cumarin has proved to be as toxic as in water cultures, while vanillin behaved approximately the same way as in the soil. Vanillin is evidently toxic only in a liquid medium when it is applied in mass, but not when it is distributed as films over quartz grains or soil particles.

5. The ameliorating effect of phosphoric acid on the action of cumarin reported in Bulletin 77 of the Bureau of Soils would not seem to be due to its antagonistic behavior with reference to that toxin, since it did not behave in the same way in a balanced solution. The ameliorating effects reported might be due either to the residual effects of the base after the phosphate radical was used up, or to the fact that cumarin does not interfere with the absorption by the plant of phosphoric acid while it does interfere with the absorption of the other food elements.

6. The behavior of toxic substances is so different in the soil than in water cultures, that one is hardly justified in drawing conclusions from results obtained with water cultures as to what might take place under actual field conditions.

ACKNOWLEDGMENT.

The writer is indebted to Dr. T. L. Lyon, under whose direction this work was done, for his kind assistance and valuable suggestions.

FIG. 1. Method of Taking Soil Samples with Sampler for Soil Bacteriologists. (See article by H. A. Noyes.)

FIG. 2. Graniteware Pots Showing the Outlet Tubes at the Bottom and the Hemispherical Funnels Inserted through the Wax Seal. (See article by A. G. McCall.)

SOIL SAMPLING FOR BACTERIOLOGICAL ANALYSIS.[1]

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INTRODUCTION.

In connection with research work on an Adams fund project in orchard management under investigation in this department it is necessary to follow the biochemical changes occurring in the soil. The plats are in clean culture, in cover crop, in sod and in sod with added mulching of grass and straw. This paper discusses the different methods of sampling soils for bacteriological analysis which were considered in connection with this experiment. It gives the results of an investigation conducted to find out which method would furnish representative samples of soil and which would interfere least with the cultural practices or the root systems of the trees. It is hoped that these results may be suggestive to those who are undertaking similar bacteriological studies.

There are three generally accepted methods for investigating the growth of plants: Field culture, plat culture, and pot culture. The method of sampling soil should be equally applicable where any of these cultural methods are practiced.

METHODS OF SAMPLING PREVIOUSLY EMPLOYED.

King and Doryland[2] have described a soil sampler which takes only a 5 c.c. sample of soil. This sample is too small to be of much use to the soil bacteriologist. To use this sampler efficiently, it is necessary to dig a hole at least a foot square to the depth the samples are to be taken. The digging of holes is detrimental to any investigation which is to extend over a period of years, as the cultural methods are disturbed. Monthly samplings would soon destroy small plats if triplicate samples are taken on each plat.

[1] Contribution from the Research Chemistry and Bacteriological Laboratory, Purdue Agricultural Experiment Station. Received for publication May 10, 1915.

[2] King, W. E., and Doryland, C. J. T., The Influence of Depth of Cultivation upon Soil Bacteria and their Activities, Kans. Agr. Expt. Sta. Bul. 161, p. 225–228. 1909.

The soil auger was used by Conn[3] for taking soil samples for bacteriological analysis. The auger does not furnish samples which are suitable for bacteriological purposes. No matter how careful one is, some soil always falls back into the auger hole and the sample is scraped against the different layers of soil as the auger is pulled out of the ground. Brown,[4] in discussing methods of sampling, writes:

"It was decided that this (the auger) method allowed opportunity for contamination of the deeper soil layers."

The number of bacteria in soil that is covered with sod or vegetative mulching is different from the number in soil under different practices of clean cultivation or dust mulching. The quantity of soil which falls back into the sampling hole on plats under different systems of cultivation varies. On one plat it may be from the layer of soil having the greatest number of microorganisms, while on another plat it may be from the layer having the smallest number of microorganisms.

The slice method is claimed by many to be the most accurate though not always the most practical method of sampling soil. This method when used for obtaining samples of soil for bacteriological analysis is open to the following objections: The spade is difficult to sterilize and to keep sterile because of its size. The cultural methods are interfered with, for holes have to be dug before the slices can be taken, and unless great care is exercised in cutting the slice variations in thickness may easily change the average bacterial content of the soil 300,000 bacteria per gram of soil. To get even fair results with the slice method the soil has to be quite moist. In fact, some types of soil can not be sliced.

The method of sampling employed at the Iowa station[5] is described as follows:

"The surface 2 or 3 inches of soil were removed from an area about 20 inches square, the soil in that area was stirred and thoroughly mixed to a depth of 4 to 6 inches and the samples were drawn and taken to the laboratory in sterile glass jars."

[3] Conn, H. Joel, An Examination of Some More Productive and Some Less Productive Sections of a Field, Cornell Univ. Agr. Expt. Sta. Bul. 338, p. 70. 1913.

Conn, H. Joel, Bacteria of Frozen Soil, New York State Agr. Expt. Sta. Tech. Bul. No. 35, p. 9. 1914.

[4] Brown, P. E., Bacteria at Different Depths in Some Typical Iowa Soils, Iowa Agr. Expt. Sta. Research Bul. No. 8, p. 287. 1912.

[5] Brown, P. E., Bacteriological Studies of Field Soils I, Iowa Agr. Expt. Sta. Research Bul. No. 5, p. 194. 1912.

The following is taken from a recent publication from the same station.[6]

"The method of sampling employed in this work was the same as has been given in the previous reports of the study of field soils. . . . The method continues to prove satisfactory and to justify claims which have been made for it."

It seems probable, however, that if the removal of the 2 or 3 inches of soil permits better comparison between parts of fields or plats under the same systems of cultivation and cropping, the removing of this layer of soil would seriously impair any comparison between plats in grass, in buckwheat, in corn and in summer fallow.

Samples of soil taken by any of the methods so far cited are aerated and the layers of soil are mixed together in the field at the time the sample is taken. The new environment thus made for the soil organisms should be avoided, especially if the samples can not be analyzed for some hours after they are taken.

The New Method of Sampling.

A soil sampler for soil bacteriologists was recently advocated by the author of this article.[7] The object was to furnish a piece of apparatus which would sample the soil accurately whatever the system of cultivation and become the container for the sample after it is taken. This sampler, which is shown in figure 13, is a brass tube 9 inches in length and 2 inches in diameter, open at both ends. One end is sharpened to a cutting edge. This cutting edge is so made that the core of soil is cut out and the compaction of soil that is necessary in order to make room for the sampler takes place outside the tube. The cutting end is fitted with a tight fitting 2-inch brass cap. The uncapped end plugged with cotton makes the sampler complete. This sampler embodies at least four of the principles that a good sampler should have: (1) It is easily sterilized and kept sterile; (2) it is easy to use; (3) it takes and keeps the sample of soil free from contamination; and (4) it is durable. The method of taking samples with this sampler is shown in Plate IV, figure 1.

The directions for using this apparatus are as follows: Plug and cap as many samplers as you wish to take samples of soil. Sterilize them in a hot air sterilizer and take them to the field. Remove the cap from a sampler, insert the driving head above the cotton plug and drive the sampler into the ground to the desired depth. Pull it

[6] Brown, P. E., Bacteriological Studies of Field Soils III, Iowa Agr. Expt. Sta. Research Bul. No. 13, p. 429. 1913.

[7] Noyes, H. A., A Soil Sampler for Soil Bacteriologists. Paper presented at meeting of Society of American Bacteriologists, December, 1914. Abstracted in Science, 42: 317. 1915.

out, flame and return the cap, and sample is ready to take to the laboratory.

Comparison of Methods of Sampling.

Of the methods previously described the sampler for soil bacteriologists, the soil auger, the Iowa station method, and the slice method were thought worthy of investigation and comparison. The method of the Iowa station was modified in that a plat 2 feet square instead of 20 inches square was laid off and no surface soil was removed.

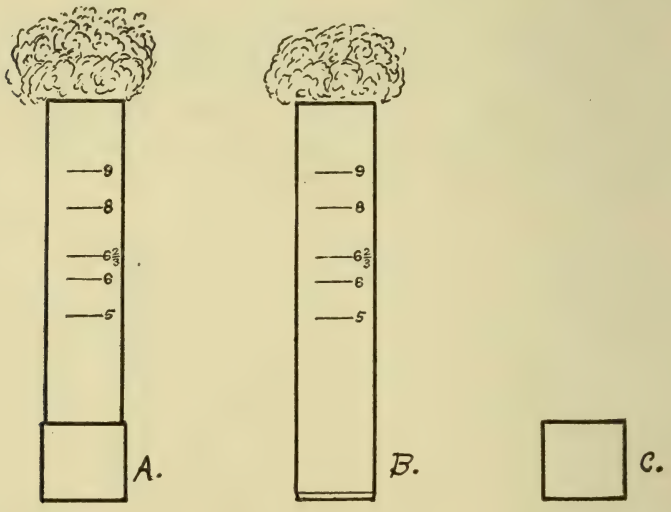

Fig. 13.—Sampler for taking soil samples for bacteriological analysis: *A*, Sampler complete; *B*, sampler without cap; *C*, cap.

The method followed at the Iowa station samples the largest unit area of any of the methods, 2 feet square, hence that area is used as the basis for all comparisons. Two samples were taken from this plot with samplers, two with a 2-inch soil auger, two by attempting to mix all the soil in the plot to a depth of 9 inches, and two by the slice method. The method which gave the most uniform samples of the 2-foot area sampled was to be considered the best method of sampling soils for bacteriological analysis. For convenience, the method of the Iowa station is designated henceforth as the "whole plot method," and the soil sampler for soil bacteriologists as "the sampler."

The procedure followed in taking the samples by the different methods follows: A plot 2 feet square was laid off, two of the samplers were driven to a depth of 9 inches on opposite sides of and

within the plot, drawn, capped and laid by. Then two samples were taken, one from each set of three borings made to a depth of 9 inches with a soil auger on each of those sides of the plot where the soil samplers had been driven. These two samples were put in sterile Mason jars and immediately put inside the carrying case away from the light. Next, the soil of the plot was spaded over until it appeared to be mixed thoroughly to a depth of 9 inches. A sample was then taken and put in a sterile Mason jar. The soil was mixed again and another sample taken. The soil was then thrown out, making a hole 2 feet square and 9 inches in depth. Lastly, on the same sides of the square and near where the former samples had been taken with the samplers and auger, two more samples were taken by cutting slices of soil about 1 inch thick from the surface to a depth of 9 inches. Sets of samples were taken in this manner on each of five dates. Counts were made from one set on 12 percent gelatin and on the other four sets on modified agar.[8] Where one method was dropped the procedure remained the same for the other methods.

In the laboratory, all samples of soil were mixed thoroughly. Fifty-gram quantities of the field soil then were put in sterile bottles with 200 c.c. of sterile water and shaken for five minutes. One c.c. of the soil emulsion thus made was put with 99 c.c. of sterile water and shaken thoroughly to give a dilution of 1 to 400. Dilutions of 1 to 40,000 and 1 to 400,000 were then made from this by adding 10 c.c. aliquots of the less dilute samples to 90 c.c. of sterile water and shaking. One c.c. portions of the 1 to 40,000 and 1 to 400,000 dilutions were plated on modified agar and incubated at 70 to 72° F. The figures given in the following tables are the average of triplicate plates and both dilutions. Some perhaps may contend that some figures given in the following tables are too uniform or that the differences are so small that the counts are meaningless. The uniformity with which the samples were handled and the care used in weighing out the 50-gram aliquots of field soil taken for analysis, in making the dilutions, and in plating were bound to produce results that showed comparisons between the different methods of sampling. The results obtained with the first set of samples are given in Table 1.

Set of Samples No. 1.

The samples from which results are reported in Table 1 were taken the day after a rain and were analyzed within two hours. Counts

[8] Brown, P. E., Methods for Bacteriological Examination of Soils, Iowa Agr. Expt. Sta. Research Bul. No. 11. 1913.

were made in 12 percent gelatin. The sampler gave the least variation in counts on duplicate samples of soil. It also gave a higher

TABLE 1.—*Millions of Bacteria per Gram of Dry Soil as Determined by 4 Methods of Sampling on a Brown Sandy Loam from a Clean-cultivated Young Orchard.*

Method of Sampling.	Lot 1.	Lot 2.	Average.	Variation.
Sampler	6.707	6.635	6.671	0.072
Soil auger	6.627	8.999	7.813	2.372
Whole plot	4.976	5.694	5.335	0.718
Slice	4.739	10.952	7.846	6.213

count than the method using the whole plot, tending to show that soil can not be thoroughly mixed in place to a desired depth. The soil at the lower depth contained more bacteria, for the samples were taken soon after rain and some of them had undoubtedly been washed down into the soil.

SET OF SAMPLES NO. 2.

The second set of samples was taken from a brown loam soil plowed in the spring and on which a dust mulch was maintained throughout the season. At the time the samples were taken, there was a 2-inch dust mulch. The samples were analyzed immediately after they were taken and the counts made on modified agar. The results are shown in Table 2.

TABLE 2.—*Millions of Bacteria per Gram of Dry Soil as Determined by 4 Methods of Sampling a Brown Loam.*

Method of Sampling.	Lot 1.	Lot 2.	Average.	Variation.
Sampler	11.197	10.920	11.058	0.277
Soil auger	8.775	10.178	9.477	1.403
Whole plot	8.532	9.646	9.089	1.114
Slice	7.936	11.357	9.647	3.421

As shown in Table 2, the sampler again gave the largest and most uniform counts. The counts obtained with the sampler are believed to be nearest the true bacterial content of the soil, as the dust mulch hindered in taking the slice, made mixing of the whole plot difficult, and affected the efficiency of the auger.

SET OF SAMPLES NO. 3.

The third set of samples was taken from a sandy soil in bluegrass sod. This soil contained but 7 percent of moisture at the time the samples were taken. The samples were analyzed immediately and the counts made on modified agar. Table 3 shows the data obtained.

TABLE 3.—*Millions of Bacteria per Gram of Dry Soil as Determined by 3 Methods of Sampling a Sandy Soil in Bluegrass Sod.*

Method of Sampling.	Lot 1.	Lot 2.	Average.	Variation.
Sampler	2.76	2.85	2.81	0.09
Whole plot	3.01	2.89	2.95	0.12
Slice	2.01	1.87	1.94	0.14

The soil auger was not used in this set, as the moisture content of the soil was so low that the soil would not hold in the auger. The sampler and the whole plot methods, on account of the low bacterial content of the soil, give practically the same results. It seems that the whole plot method gives the higher count because many of the bacteria probably were about the grass roots and this method gave a sample containing more sod than the others. Great difficulty was experienced in taking the slice samples and counts show that the samples thus secured were not representative. For the third time, it is evident that the sampler takes the more representative and uniform samples from the two-foot-square plots.

SET OF SAMPLES NO. 4.

The sampler having given the most representative counts and the least variation in counts on all three sets of soil, it was compared with other methods on the least uniform soil that was readily available. This was a mixture of manure, muck, compost, and sand which had recently been put into a new greenhouse over a gravel soil. The added material formed a layer about 6 inches in depth. The samplers, the slice and the method involving the mixing of the 2-foot square plot of soil were the methods used in this test. The samples were taken as before in duplicate and then the whole set of samples was duplicated, giving two complete sets of samples. One set was analyzed immediately and the other was allowed to remain in the samplers and Mason jars for five days before being analyzed. The counts were made on modified agar. The results, expressed in millions of bacteria per gram of dry soil, are given in Table 4.

TABLE 4.—*Millions of Bacteria per Gram of a Dry Greenhouse Soil, as Determined by 3 Methods of Sampling.*

Method of Sampling.	Analyzed Immediately.		Analyzed After 5 Days.	
	Average.	Variation.	Average.	Variation.
Sampler	5.479	0.988	4.780	0.279
Whole plot	6.181	0.083	6.239	1.383
Slice	4.294	0.318	4.319	1.232

The more a nonuniform soil is mixed the more uniform it becomes and thus it is to be expected that the whole plot method would give the most uniform results on this soil. The sampler appeared to take the more unrepresentative samples of soil as evidenced by the variation between duplicates where the samples were anaylzed immediately after they were taken. It did, however, take samples more nearly representing the upper 9 inches of soil. From the composition of this soil, the greater number of organisms was in the upper mixtures which, in reality, were sampled by the whole plot method. The samples were air-dried and sieved and it was found that those taken with the samplers contained 10.5 percent of stone which would not pass through a 1.5 mm. sieve. Those samples taken by the whole plot method contained only 5.8 percent of stone which would not pass through the 1.5 mm. sieve.

The counts made on the samples that were held five days showed that the samplers kept the soil in a condition more nearly approximating that in the greenhouse. The samples were held at a lower temperature than the temperature of the greenhouse soil and thus a lowering in count is better than the same count or a larger count. The samplers kept the layers of soil intact and did not mix together the groups of microorganisms present at different depths or aerate the soil, as must be done if it is put in storage jars. The sampler keeps the soil in practically the same relationship to the air that it is in the field, whereas in the jars conditions are changed and errors arise that are dependent on the length of time that the samples are kept before analyzing.

Changes in Nitrate Content.

The following determinations (Table 5) of the nitrates present in the samples of greenhouse soil tend to show that the sampler will keep a sample of soil in the condition least favorable to changes in bacterial activities.

Table 5.—*Nitrates in a Greenhouse Soil Sampled by Various Methods as Determined at Time of Sampling and After Standing Five Days.*
(Determinations in milligrams of NO_3 per gram of dry soil.)

Method of Sampling.	Analyzed Immediately.		Analyzed After 5 Days.		Change.
	Average.	Variation.	Average.	Variation.	
Sampler.....	0.305	0.017	0.314	0.012	0.009
Whole plot....	0.298	0.044	0.366	0.000	0.068
Slice.....	0.263	0.008	0.343	0.114	0.080

There are two things in Table 5 that are apparent. The sampler does not show the least range between duplicates in either case, and it holds the soil in that condition in which the nitrates remain practically unchanged. The former is explained by the nonuniformity of the soil. The latter proves that the sampler does keep the soil in that condition in which the biochemical activities tend to remain the same as under field conditions.

Several tests made of soils under different conditions show that the soil is not appreciably compacted in the sampler unless it is driven into the ground with exceptionally heavy blows or the soil is exceptionally loose. The results of these tests are shown in Table 6. In method *A* the sampler was driven into the soil with three medium drives between measurements, and in method *B* it was driven with three violent drives.

Packing of Soil in Sampler.

Table 6.—*Effect on Compactness of Soil of Methods of Taking Samples with the Soil Sampler.*

Condition of Soil.	Method A.			Method B.		
	Depth of Soil.		Compression.	Depth of Soil.		Compression.
	In Sampler.	Around Sampler.		In Sampler.	Around Sampler.	
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Tramped garden	2.50	2.50	0.00	3.00	3.25	0.25
	4.50	4.75	0.25	4.50	4.87	0.37
	6.50	6.65	0.15	5.75	6.25	0.50
Soy bean stubble	2.25	2.25	0.00	3.75	4.00	0.25
	4.75	4.75	0.00	6.50	6.90	0.40
	6.75	6.87	0.12	.....	.....	.....
Bluegrass sod	2.00	2.00	0.00	2.87	3.00	0.13
	3.25	3.25	0.00	4.75	4.75	0.00
	4.75	4.87	0.12	6.25	6.50	0.25
	6.00	6.25	0.25	.....	.....	.....
	7.00	7.25	0.25	.....	.....	.....
Newly spaded garden	2.25	2.50	0.25	5.00	6.50	1.50
	3.25	3.75	0.50	6.75	8.50	1.75
	4.50	5.00	0.50	.....	.....	.....
	6.75	7.37	0.62	.....	.....	.....

In this work an attempt has been made to investigate methods of sampling as they would be followed in comparative studies. When samples are desired at different methods on a soil type there are two ways of taking them: (1) By taking the samples directly as you dig, bore, or drive down into the soil; and (2) by digging

a hole and taking samples from the lateral surfaces of soil at the depths desired. In most work of this kind errors arise because the soil sample is aerated. Samplers of different diameters and lengths would permit one, if he used those samplers of largest diameter first, to sample the soil to different depths without much contamination from the upper layers of soil. The upper portion of the core of soil obtained in this way should not be used in other than the first portion as that part of the sample has been exposed to the air.

The sampler is adapted to horizontal use in pits, but here again the portion of soil nearest to the cotton plug should not be used for analysis, as this portion has been aerated.

Summary.

1. It is harder to obtain uniformly representative samples of soil for bacteriological analysis that it is for chemical and physical analysis.

2. The errors which must arise from employing various methods of sampling soils for bacteriological analysis vary with the method employed, the physical condition of the soil, and the vegetative growth on the soil.

3. Experimental work in investigating the growth of crops on soil is conducted by field tests, plot tests, and pot tests. The method of sampling should be one which can be used in connection with these tests.

4. Different crops and different systems of cultivation effect changes in the environment of the bacteria in a given set of experiments and hence change the bacterial flora of the soil.

5. An official method for sampling soils for bacteriological analysis should be one which would sample soils subjected to different cropping and systems of cultivation with the same accuracy.

6. Samples of soil used for bacteriological analysis should be representative, taken free from and kept free from contamination, and should be kept until analyzed in that condition in which the bacterial processes of the soil are not altered.

7. A soil sampler for bacteriological purposes should be easy to sterilize, easy to manipulate, and durable.

8. The slice method in comparison with the methods of the Iowa station and the soil sampler for bacteriologists does not give uniformly representative samples of soil.

9. The soil auger is unsuitable because it gives unrepresentative samples of soil for bacteriological purposes and because it can not be used at all on some soil types.

10. The method employed by the Iowa station gives better results than either the slice method or the auger method, but not as good results as are obtained with the soil sampler for soil bacteriologists.

Conclusions.

The brass soil sampler described in this article, which embodies the principles of the steel cylinder used for sampling soil, the pipette box, and the cotton plug, is the best apparatus investigated for obtaining samples of soil for bacteriological purposes, for it is easy to sterilize, easy to use, and is durable. This sampler, when used in comparison with the Iowa station method, the soil auger method, and the slice method for taking samples of soil for bacteriological analysis on different types of soil and soil under different systems of management, takes the most representative samples for bacteriological purposes. It also prevents contamination of the sample and by becoming the container of the sample keeps it until analyzed practically under field conditions. This method of sampling does not interfere with the cultural methods followed on the plots or pots under investigation.

Acknowledgment.

The author wishes to acknowledge with thanks the assistance of Mr. Edwin Voigt in carrying out this investigation.

The successful development of a sampler suitable for bacteriological purposes was in no small measure due to the cooperation of the Central Scientific Company. The author wishes to thank them for making trial samplers according to his specifications without charge.

A NEW METHOD FOR THE STUDY OF PLANT NUTRIENTS IN SAND CULTURES.[1]

A. G. McCall,

Johns Hopkins University, Baltimore, Md.

The time is rapidly approaching when the agronomist must turn to water and sand cultures for the solution of the physiological problems of plant nutrition which he is constantly encountering, not only in the field but also in his pot cultures.

[1] Contribution from the Laboratory of Plant Physiology, Johns Hopkins University. Received for publication July 6, 1915.

The recent publications of Tottingham[2] and of Shive[3] have suggested the desirability and importance of having some method by which the effect of different nutrient solutions upon plant growth might be studied in the presence of some solid substance similar to the soil, but at the same time furnishing fewer chemical and biological complications. Acting upon this suggestion the writer has devised a method by which seedlings may be grown in sand and the nutrient solution renewed or modified almost as readily as in water cultures.

The accompanying illustration (Pl. IV, Fig. 2) shows the type of pot used in duplicating in sand some of Shive's work with wheat seedlings in solution cultures. The pots are of graniteware, approximately 12×12 centimeters inside, tapering slightly at the base and having a wide projecting rim at the top. When filled to within about 3 centimeters of the top, they hold 1,500 grams of dry quartz sand. To provide for the removal of the solution a small lead tube is soldered into the side as near the bottom as possible. The soldered joint and the lead tube are covered with paraffin to guard against lead poisoning and the outlet closed by means of a short length of rubber tubing provided with a pinch-cock. The description of the method given in the following paragraphs includes the details of manipulation from the starting of the seedlings to the harvesting of the plants.

The seed is soaked in water and the seedlings grown, in the manner described by Tottingham,[4] to a height of about 3 or 4 centimeters, when they are ready to be transferred to the sand cultures. While the seed is being germinated 1,500 grams of dry quartz sand (previously washed several times with distilled water) are weighed into the pot, the outlet at the bottom of the pot being screened on the inside by means of a plug of glass wool inserted before the pot is filled. With the pinch-cock closed distilled water is now added to the pot until the sand is completely saturated, after which the pinch-cock is opened and the surplus water allowed to drain out through the tube at the bottom of the pot until the last free water has disappeared from the surface of the sand. A hemispherical clay funnel is placed in position as shown in the photograph and the pot is then ready to receive the seedlings.

[2] Tottingham, W. E., A Quantitative Chemical and Physiological Study of Nutrient Solutions for Plant Cultures, Physiological Researches, Vol. I, No. 4, May, 1914.

[3] Shive, J. W., A Three-Salt Nutrient Solution for Plants, Am. Jour. Bot., 4: 157–160, April, 1915.

[4] L. c., p. 176.

After careful selection for uniformity, the seedlings, six in number, are planted equal distances apart on a circle drawn midway between the edge of the funnel and the wall of the pot. Care is taken to have the seedlings at such depth that the top of the grain is just level with the surface of the sand. After all of the seedlings are in place the pinch-cock is closed and the pot is tapped gently on the top of the table until free water appears on the surface of the sand. This manipulation serves to pack the sand around the roots of the seedlings and at the same time to level the surface of the sand preparatory to putting on the seal of Briggs and Shantz[5] wax. The surplus water is then drawn out of the pot by application of suction (by means of an aspirator) to the tube at the bottom and a thin layer of the melted wax is flowed over the surface, completely covering the surface of the sand between the funnel and the wall of the pot. Care should be taken not to have the wax too hot, or the seedlings may be injured at the point of contact between the wax and the plant. The surface must be sealed to prevent loss of water by evaporation from the surface of the sand and of course the walls of the pot must be impervious to moisture in order that transpiration can be measured and the concentration of the nutrient solution controlled.

The pot is now ready to receive the nutrient solution, which is added through the funnel at the top while the water is being removed at the bottom by the application of suction to the outlet tube. A double or triple portion of the nutrient solution is passed through the sand at this first application in order to flush out the distilled water. The pot is now placed on the scales and the removal of solution is continued until the sand has been reduced to the desired moisture content, which should be as near the optimum as possible. At the end of each three-day period the pot is weighed and sufficient water is added through the funnel to bring the system back to its original weight. A fresh nutrient solution is now added in the desired amount (250 c.c. for pots of this size), while an equivalent quantity of solution is removed at the bottom. A nutrient solution of the same concentration may be used throughout the entire period of growth, or it may be varied from time to time as the plants continue to develop. The plants may be harvested at any time by removing the wax seal and cutting them level with the surface of sand. If desired, the roots may be recovered from the sand by washing them out with a jet of water. The weight records will give the trans-

[5] Briggs, L. J., and Shantz, H. L., The Wilting Coefficient for Different Plants and its Indirect Determination, U. S. Dept. Agr., Bur. Plant Indus. Bul. No. 230, p. 13, 1912.

piration of each culture and the harvest records can be made to include the dry weights of both tops and roots.

This method also furnishes a means by which the original concentration of the solution can be compared with its concentration after contact with the soil and with the plant roots. The method is superior in many ways to water cultures because it permits the plants to be grown under conditions that approximate those found in the field, so far as the substratum is concerned, and it seems probable that with some slight modifications which are now in progress it will be possible to apply the method to cultures grown in sandy and sandy loam soils.

AGRONOMIC AFFAIRS.

NOTES AND NEWS.

Paul S. Baker has been appointed assistant in agronomy at the Pennsylvania college and station.

The resignation of Dr. M. A. Brannon as president of the University of Idaho, announced in the July–August JOURNAL, has been withdrawn and Dr. Brannon will remain at Moscow.

James W. Cantwell, formerly superintendent of schools at Fort Worth, Texas, has been elected president of the Oklahoma College of Agriculture.

During the latter half of May and the first half of June Geo. N. Coffey of the University of Illinois assisted the Ontario Agricultural College in beginning a general soil survey of the Province of Ontario. This is the first soil survey work which has been done in Canada.

Kenneth Cole is now assistant in agronomy at the Maryland station.

John Lee Coulter of the Knapp School of Country Life, Peabody College, Nashville, Tenn., has been elected dean and director of the West Virginia college and station. Dr. Coulter's work has been largely along the line of rural economics. For two years he was assistant professor of rural economics at the University of Minnesota and more recently was special agent in charge of editing and compiling the figures on agriculture for the 1910 census.

F. L. Duley has been appointed research assistant in soils at the Misouri station.

E. C. Johnson, for the past three years in charge of farmers' institutes in Kansas, has been elected dean of the extension division of the Kansas college, succeeding J. H. Miller, who is now dean of extension in Arkansas.

Lewis A. Merrill, for a number of years agronomist of the Utah station and more recently engaged in commercial work in agronomy at Salt Lake City, was killed in an automobile accident near that city, on June 1. He had been a member of this society since 1909.

C. P. Norgord has been appointed commissioner of agriculture in Wisconsin. He will be at the head of the newly organized department of agriculture in that state, in which several offices having to do with agricultural affairs are now combined.

Glen S. Ray, a graduate of the Colorado Agricultural College, has been appointed assistant in farm crops in the University of Idaho.

Robert Stewart, for the past several years professor of chemistry and chemist of the Utah college and station, on September 1 became associate professor of soil fertility in the University of Illinois and assistant chief in soil fertility in the Illinois station.

Theodore Stoa of the North Dakota station has been appointed a scientific assistant in cereal investigations in the U. S. Department of Agriculture.

Chas. S. Van Nuis has been appointed associate agronomist in the New Jersey station and manager of the college farm, succeeding Irving L. Owen, who becomes county farm demonstrator in Middlesex County.

The following officers were elected at the meeting of the Great Plains Cooperative Association at Mandan, N. Dak., July 14–16: President, Director W. L. Carlyle of the Oklahoma station; vice-president, Supt. J. F. Ross of the Amarillo Cereal Field Station; secretary, E. C. Chilcott, of the U. S. Department of Agriculture; and as additional members of the executive committee, W. W. Burr and C. W. Warburton of the U. S. Department of Agriculture and L. E. Call of the Kansas station.

H. H. Bartlett, of the bureau of plant industry, U. S. Department of Agriculture, has been appointed assistant professor of botany in charge of genetics in the University of Michigan.

W. C. Etheridge, for the past three years engaged in graduate study at Cornell University, is now in charge of the department of agronomy in the University of Florida.

E. P. Humbert, agronomist of the New Mexico college and station, has been appointed dean of agriculture. J. G. Hamilton has been appointed assistant agronomist in New Mexico.

John H. Voorhees, formerly agronomist in the extension division of the New Jersey college, is manager of Franklin Farms, Mendham, N. J.

Louis Wermilskirchen, scientific assistant at the Amarillo (Tex.) Cereal Field Station of the U. S. Department of Agriculture, has been appointed superintendent of the State station farm at College Station, Tex.

Joseph E. Wing, a prolific writer of agricultural books and newspaper articles, died September 10 of pellagra in a sanitarium near his home, Mechanicsburg, Ohio.

Interstate Cereal Conference.

An Interstate Cereal Conference was held at the University of California, Berkeley, Cal., June 2, 1915. Dr. J. W. Gilmore of the University of California was elected chairman, and Chas. E. Chambliss of the U. S. Department of Agriculture, secretary. The executive committee consists of the officers and Messrs. M. A. Carleton, F. S. Harris, and Bert D. Ingles. Fifteen papers were presented at the meeting. On June 1 the cereal crops in the vicinity of Stockton, Cal., were inspected by many of those who attended the conference. On June 3 and 4 the cereal experiments of the University of California at Davis and of the Office of Cereal Investigations, U. S. Department of Agriculture, at Chico and Biggs, Cal., were inspected.

Meetings of the Society.

A joint session of the American Society of Agronomy and the Great Plains Cooperative Association was held at Mandan, N. Dak., July 14–16, 1915. About 80 persons attended the meeting and about 25 papers were presented. More than half of those in attendance and more than half of those who presented papers were members of the society.

The eighth annual meeting of the American Society of Agronomy was held at Berkeley, Cal., August 9 and 10. The program was presented practically as published in the July–August number of the Journal. Officers for 1916 were elected as follows: President, C. R. Ball of the U. S. Department of Agriculture; first vice-president, Alfred Atkinson of the Montana station; second vice-president,

A. N. Hume of the South Dakota station; secretary, C. W. Warburton, of the U. S. Department of Agriculture; and treasurer, George Roberts of the Kentucky station. A full report of the meeting and of the various officers and committees will be published in the November–December JOURNAL.

MEMBERSHIP CHANGES.

The membership reported in the July–August number of the JOURNAL was 444. Fifteen new members have been added since that time, while 1 has resigned and 1 has died, making the total membership at present 457. The number of new members received in 1915 is now 93. The names of members deceased and resigned, new members not previously reported, and recent changes of addresses are as follows:

MEMBER DECEASED.

L. A. MERRILL.

MEMBER RESIGNED.

D. S. FOX.

NEW MEMBERS.

BAILEY, C. H., University Farm, St. Paul, Minn.
BASSETT, L. B., 2095 Dudley Ave., St. Paul, Minn.
EMERSON, F. V., 715 Boyd Ave., Baton Rouge, La.
HALL, THOS. D., 301 Bryant Ave., Ithaca, N. Y.
HARPER, J. D., Purdue University, West LaFayette, Ind.
HARRINGTON, OSCAR E., Experiment Station, East Lansing, Mich.
KNUTSON, GEO., Great Western Sugar Co., Longmont, Colo.
LUÁCES, ROBERTO L., Granja Escuela, Camagüey, Cuba.
MAXSON, A. C., Great Western Sugar Co., Longmont, Colo.
MIYAKE, KŌJI, 2316 Fulton St., Berkeley, Cal.
PIETERS, A. J., 340 Blair Road, Takoma Park, D. C.
PIPER, GEO., Glendive, Mont.
RUDOLPH, E. G., The Dakota Farmer, Aberdeen, S. Dak.
THYSELL, JOHN C., Dickinson Substation, Dickinson, N. Dak.
VOIGT, EDWIN, 20 Waldron St., West LaFayette, Ind.

ADDRESSES CHANGED.

CURREY, HIRAM M., c/o C. S. Bowne, Aumsville, Ore.
DOUGLASS, T. R., Iowa State College, Ames, Iowa.
DYNES, O. W., New York State College of Agr., Ithaca, N. Y.

LECHNER, H. J., Washington State Normal School, Ellensburg, Wash.
MCCALL, ARTHUR G., Ohio State Univ., Columbus, Ohio.
STEWART, ROBT., Univ. of Ill., Urbana, Ill.
MACKIE, W. W., 1358 Scenic Ave., Berkeley, Cal.
YODER, P. A., Cairo, Georgia.

COMING EVENTS.

Under this caption it is proposed to keep standing a schedule of coming meetings of various organizations more or less closely connected with agronomy. Secretaries of such bodies are invited to furnish information regarding their meetings.

SEVENTH GRADUATE SCHOOL OF AGRICULTURE.

Massachusetts Agricultural College, Amherst, Mass., July, 1916.

SECOND PAN-AMERICAN SCIENTIFIC CONGRESS.

Washington, D. C., December 27, 1915—January 8, 1916.

LOCAL SECTIONS.

IOWA STATE COLLEGE AND EXPERIMENT STATION.
President, Ross L. Bancroft.
Secretary, R. A. Needham.

KANSAS AGRICULTURAL COLLEGE AND EXPERIMENT STATION.
President, W. M. Jardine.
Secretary-Treasurer, C. C. Cunningham.

WASHINGTON, D. C.
President, H. N. Vinall.
Secretary-Treasurer, P. V. Cardon.

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THE WORK OF THE AMERICAN AGRONOMIST.

CHARLES E. THORNE,

OHIO AGRICULTURAL EXPERIMENT STATION, WOOSTER, OHIO.

(Presidential address before the American Society of Agronomy, August 9, 1915.)

The ultimate purpose of the work of the scientific agronomist is to increase the production of food and clothing for humanity. He has been called to this work in response to the evident proposition that population can not continue indefinitely to increase at the rate which is now prevailing unless there is a corresponding increase in the rate of food production. It is true that the lines of human increase and of food production, for the world at large, are approaching each other far less rapidly than has been anticipated by some who have prophesied on this point, but nevertheless none can deny that the average acre must be taught to yield more liberally than it is now doing if future generations are to be fed and clothed adequately.

Within the space of a lifetime the art of agriculture has passed through a tremendous revolution. I myself have witnessed the reapers bending their backs to gather the wheat on an Ohio farm with an implement which had been practically unchanged since man first learned the use of iron. I have seen the mowers swinging their way through the meadow and have listened to the rhythmic thud of the flail on the thrashing floor. I have seen the wooden plow, with its iron share, lying only recently discarded in my grandfather's barnyard, and have witnessed every forward step from these crude implements of husbandry, which had been practically unchanged for thousands of years, to the elaborate farm machinery of today, by which

one man can accomplish more in many lines of work than was possible to ten men sixty years ago.

This progress in mechanical invention, which has wrought a still greater revolution in transportation than in agriculture during the same period, has made it possible to spread our corn and wheat fields over this new land of ours until we have reached the limit of the naturally watered land and are now attacking the desert with great schemes of irrigation. The westward tide of migration, reaching the limit of the free land, has now turned upon its course and is starting eastward.

This expansion in production has been accompanied by a still greater increase in population. During the 40 years from 1871 to 1910 our production of wheat and corn doubled, as measured in 5-year periods. From 1881 to 1900, however, we were exporting more than one-third of our total wheat crop, while our exports for the 5 years from 1908 to 1912 averaged less than 15 percent of the crop, although the total production of wheat in the United States was greater during that period than for any other similar period in the history of the country. Our exports of corn have never reached any considerable proportion of the crop, the highest rate of exportation being an average of 10 percent of the total crop during the 5 years, 1896–1900, but it fell to less than 2 percent during the 5 years, 1908–1912.

The prediction made and widely published about 25 years ago that the United States would cease to be an exporter of wheat before the beginning of the present century has therefore fallen very far short of fulfillment. It cannot be questioned, however, that the tendency the world over is strongly towards the overtaking of production by consumption and that the coming generations of farmers will need all the help that the scientific agronomist can give them if the world is to continue to be sufficiently fed and comfortably clothed.

Mechanical invention can certainly not make another such advance in the production of farm crops as it has done in the past 60 years. There will be further improvements, without doubt. The plow, harrow and cultivator will probably be drawn chiefly by gasoline or electricity within the next 20 years, and the cost of transportation will certainly be further reduced by the motor truck, driven over improved roads. I freely admit that no man in my boyhood days could have predicted the progress which I have witnessed, but I believe that we have reached a plane of knowledge with reference to the laws which govern mechanical operations which justify us in

assuming that the major part of the road between what has been and what shall be in the mechanics of agriculture has been traversed.

Moreover, mechanical invention has not only done very little towards the increase of crop yields, but it has been of incalculable aid to the soil robber. The machinery for making drains and drain tiles and for the compounding and distribution of fertilizing materials has contributed to the conservation of soil fertility. On the other hand, each improvement in tillage, harvesting and transporting machinery that has reduced the amount of human labor required per acre in crop production and transportation has thereby made it possible the more rapidly, extensively and completely to deplete the soil of its fertility. It was the automatic grain binder and the transcontinental railroad which made possible the exploiting of the bonanza wheat farms of the Northwest 30 years ago, and which brought down the price of wheat to a point below the cost of its production on the eastern farm. The estimates of the United States Department of Agriculture show, however, that the average yield of wheat per acre for the country as a whole remained stationary at about twelve bushels until 1890—or until the effect of modern scientific research in agriculture began to be manifested in our wheat fields—notwithstanding the vast area of new land which was annually being brought under the plow.

More thorough drainage and deeper and more perfect tillage enable the crop to extend its feeding area and bring the stores of plant food in the soil more rapidly into available form, by improving the conditions for the chemico-biological action by which the first steps are taken in the conversion of stones into bread. The experience of the ages has shown that, excepting the few small areas in which the fertility of the soil is maintained by materials carried from other lands and deposited in periodic floods, the natural stores of plant food in the soil, abundantly sufficient as they seem, when viewed in the crude mass, to maintain crop yields indefinitely, are nevertheless so inert that the portion which the crop is able annually to obtain, even under the best systems of drainage and tillage, sooner or later falls below the point of profitable cultivation.

The course of crop production under the empirical system of agriculture which has hitherto prevailed is well illustrated by the statistics of corn and wheat production in Ohio, in which State these statistics have been collected by the township assessors since 1850. From its earliest history Ohio has been a large producer of both wheat and corn. The pioneer farmer found there a soil and climate admirably adapted to the growth of both grains, and he found corn

already extensively cultivated by the Indian. The lake on the north and the river on the south furnished facilities for transporting his crops to market before the advent of the railroad, and when that came it found Ohio lying in the direct pathway between the East and the West, so that there has been every inducement to extend to the utmost the production of these grains.

The outcome has been that for the 40 years from 1850 to 1889, Ohio produced about 10 bushels of wheat per capita of population, except for a few years during the Civil War and immediately after, the production keeping pace with the increase of population, which averaged nearly half a million for each decade. This gain in production, however, was due chiefly to expansion of area, the increase in yield per acre during the 40 years amounting to not more than a bushel. With the end of the eighties there began a decrease in the area sown to wheat, due largely to the depression in prices, and for the 10 years from 1900 to 1909 our production was but 6 bushels per capita, although there was a further increase of a bushel and a half in the yield per acre, an increase probably due in a considerable degree to the limitation of the wheat area to the land better adapted to this crop. Should the population of Ohio continue to increase as it has done during the last 40 years and should there be no further increase in the area sown to wheat nor in the yield per acre, that State will not be producing bread enough for its people 20 years from now.

What is taking place in Ohio will follow, sooner or later, in the nation as a whole. There will of course be some extension of the area given to wheat as soon as encouragement is offered by better prices. Ohio grew half a million more acres of wheat during the eighties, when the price averaged above a dollar a bushel, than has been grown since the beginning of the present century. An average price for a few years of a dollar and a quarter to a dollar and a half per bushel would probably add a million acres to our present area in wheat and ten to twenty millions to that of the United States, but while no limit can be set to our increase in population, there is a very definite limit to the possible area of our wheat fields.

There will also be an extension of the area sown to wheat in other countries. The possibilities of South American and South African wheat fields have not yet been sounded, nor has the limit of wheat production been reached in Siberia and Manchuria. The North American wheat grower will therefore have plenty of competition for a long time to come, and the efforts of the American agronomist should be directed towards reducing the cost of production through

better cultural methods, through improvement of varieties, and through more effective feeding of the plant.

One of the greatest sources of waste in the agriculture of Ohio is the cultivation of land which, through lack of drainage and of rational fertilization, can not by any possibility yield a full crop. For the 10 years from 1903 to 1912 our average yield of wheat was but 15¼ bushels per acre, while in many counties it was less than 12 bushels. This means that a large portion of the crop is grown on land which is giving an inadequate return for the labor expended upon it. The inferior crops which are grown on this land go to swell the total volume thrown on the market and thus to depress prices, while the men who are producing such crops are receiving less for their work than the wages of the common day laborer. We are talking effectively about the elimination of the loafing cow from our dairy herds; let us begin to talk about eliminating the loafing acre from our wheat and corn fields. We are growing twenty-eight million bushels of wheat in Ohio on nearly two million acres of land, and one hundred and eleven million bushels of corn on nearly three million acres. We are also gowing nearly a million and a half acres of oats, which yield but 34 bushels per acre. It is safe to say that the total produce of these six million acres could be grown on two-thirds the present area, and at a saving of six to eight million days' labor, under such a system of drainage, crop rotation and fertilizing as science is now ready to point out, and that this change could be brought about within ten years' time, if the cooperation of the farmer could be secured. There is no immediate urgency for a greater total production of wheat, but there is a tremendous urgency for a more economical production.

If we can demonstrate to the farmer that he can produce his present yields on fewer acres and with less labor and thereby induce him to turn back to nature a part of the land over which he is now toiling without profit or at an actual loss, even though this abandoned land be occupied by briers and thistles, both he himself and his and our posterity will be benefited. Both the wisely cultivated and the wisely uncultivated land will gain in fertility, so that when the generations that are to follow us need more bread there will be a rested and recuperated land ready to give it to them.

The first step towards the attainment of this end, east of the Missouri at least, is drainage. At a rough estimate, possibly one acre in a hundred in Ohio is naturally sufficiently drained by underlying gravels or stratified rocks. Possibly two acres in a hundred have been sufficiently drained by tiles, and possibly thirty acres in a

hundred are partially drained, either naturally or artificially, but I am confident that more than two-thirds of the land now under plow in the state is in urgent need of drainage. If the wettest half of this two-thirds were at once seeded to grass and the labor thus saved from its cultivation expended in draining the remainder a long step would be made towards better conditions.

There are hundreds of thousands of acres of land in Ohio on which a dressing of lime would immediately return 100 to 200 percent on its cost. Not all our land needs lime so urgently as this, but the agronomist is now prepared to advise the farmer intelligently on this point. This is the second step forward, for when the land needs lime neither tillage nor drainage nor crop rotation nor manuring nor fertilizing can perform its full function.

For nearly a century there has been a steady outflow of phosphorus from Ohio's farms, carried in the pioneer days in the wheat which was shipped east by the lake or south by the river and in the bones of the cattle which were driven over the mountains to the eastern cities or in those of the hogs which went down the Ohio to be converted into energy for the production of sugar and cotton. In later days this phosphorus has been dispersed still more widely as facilities for transportation increased, and today we find all the older Ohio soils so hungry for it that a judicious investment in this element returns with a few months from 200 to 500 percent.

Northwestern Ohio is a great, flat plain, very deficient in natural drainage, but with large areas of rich, black soil. Systematic drainage by organized effort has been carried farther here than in any other region of the State, and this region has increased its yields of corn by more than 8 bushels and of wheat by more than 3 bushels per acre during the 60 years of our statistical record.

Northeastern Ohio is more rolling and very little draining has been done, but a larger use of commercial fertilizers has been made in this quarter than in any other section of the State, the fertilizers being applied chiefly to the wheat crop. The outcome has been a larger gain in this section in the yield of wheat during the 60 years than in any other quarter.

Between drainage in the northwest and fertilizing in the northeast the northern third of Ohio now exceeds the average of the State in corn yield by more than 3 bushels and in wheat yield by nearly 2 bushels per acre, but the total yields attained in this section are only half what has been attained when drainage, liming, manuring, fertilizing and systematic rotation of crops have all been laid under contribution.

Drainage, lime and phosphorus are not the only amendments and reenforcements required by the average Ohio soil. The system of husbandry which has reduced its stock of phosphorus has also drawn heavily upon its stores of nitrogen and potassium, and restitution of these also must be made in some manner if potential crop production is to be attained. On some of the more exhausted lands it is possible to use commercial nitrogen and potassium with profit, but in a very great majority of cases, and ultimately in all, the object should be to obtain these elements almost exclusively from the air and the soil and to pilot the farmer successfully in this direction will require the aid of all the resources of agronomic science.

We have not as yet measured the capacity of the nitrogen-fixing organisms which we have so recently discovered. One thing is certain, and that is that we can not build up the nitrogen supply in an impoverished soil by growing an occasional crop of clover and taking off the hay. It is equally certain that we can not afford to ignore the help which the leguminous crops offer us in this direction.

Next to drainage and lime and phosphorus, the greatest need of the Ohio farm is nitrogen. How to secure this nitrogen most economically is the most intricate problem set before the agronomist. It is a problem which can not be solved in the chemical or bacteriological laboratory, nor can it be solved without the aid of the chemist and the bacteriologist, both working together and hand in hand with the agronomist, restricting this term for the moment to him who directs the practical management of farm crops as they are grown in the open field.

The harnessing of atmospheric nitrogen through the aid of electricity, announced by Sir William Crookes seventeen years ago as commercially accomplished and verified by a present annual combination of such nitrogen in quantities equivalent to that contained in more than 100,000 tons of nitrate of soda, with results so satisfactory that the capacity of the producing plants is being greatly increased, has indefinitely postponed the possibility of the supply of human food being restricted for want of nitrogen. This epoch-marking discovery, however, does not absolve us from the duty of pointing out to the farmer the methods by which the larger part of the nitrogen required by his crops may be obtained in less costly form than either nitrate of soda or cyanamid.

When scientific research in agriculture was organized under national legislation in America it was a new thing in the world and the popular concept of such research was extremely hazy. The term "agronomy" did not come into general use for many years, and those

of us who set ourselves to the study of the problems that are now included under this term went at our task in many and devious ways, because there was no lamp of experience to guide our feet. Gradually some semblance of system is being evolved out of this chaotic condition, and I believe that we have come to the time when a few general principles may be enunciated as having an important bearing upon the conduct of agronomic research.

The first of these is the necessity for a more definite knowledge of the soils upon which we are working. Whether our object be the increase of production through a more effective feeding of the plant or through a better adaptation of variety to environment, it is of the first importance that we get acquainted with our soils. The soil survey is the first step in this direction and it should be energetically pushed forward in every State. But the soil survey is a very superficial and inadequate form of research unless accompanied by chemical and biological studies and by field experiment.

By the soil survey we may classify our soils on the basis of their geological history and physical characters, and thus may be enabled to limit the far more difficult and costly field experiment to general soil types, but unless the survey is followed and its findings interpreted by field experiment it will have very little value. We may learn much by chemical analysis and by pot-cultural work, but the final answer to our questions can be obtained only in the field.

A point of fundamental importance in field experiment is the necessity for continuity of effort. Experience has shown that seasonal conditions may completely reverse the outcome of an experiment with fertilizers or varieties, and that definite advice as to farm practice can not be safely formulated until the work has passed through a considerable number of our changing seasons. The problems which confront us can never be solved by intermittent, desultory methods. The field experiment is one of the most intricate and baffling methods of investigation. The variations in soils, the changing seasons, the interplay of the chemical and biological factors in the soil of which we know so little, call for the exercise of the highest scientific training for the correct interpretation of its results, but because this work is tedious, difficult and often disappointing we are not excused for neglecting it.

The organization of scientific research in agriculture provides, and I believe wisely, for a single center of such research in each State, but the agronomist who limits his work to the single farm upon which his station happens to be located or who expects to complete his work within a season or two will make a fatal mistake.

The investigator whose goal is the classification of objects, the study of their composition or of their physical relations, may establish his facts from a comparatively few observations. The chemist, under the conditions of absolute control which prevail in his laboratory, may determine his weights and measurements with such accuracy that a single analysis may define the composition and character of the object under investigation, but the agronomist, whose chief reagent is that most mysterious of all natural forces, the life principle, and whose work is to study the relation of this principle to the physical, chemical and vital forces of soil and air and sunshine, under the ever-varying whims of climatic change, must go at his work in the knowledge that when the grayness of age has overtaken him his task will have been only fairly begun.

FURTHER EVIDENCE OF THE IMMEDIATE EFFECT OF CROSSING VARIETIES OF CORN ON THE SIZE OF SEED PRODUCED.[1]

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Introduction.

There is abundant evidence which goes to prove that crossing varieties or strains of corn frequently increases the yield, especially in the first hybrid generation. Corn differs from most other plants in that the effect of crossing can be seen the current year. This is due to xenia, or the hybridization of the endosperm as well as of the embryo.

The first recorded experiments along this line seem to have been made by Professor Beal (1),[2] beginning in 1876, and these experiments were followed by those of Sanborn (15), McCluer (12), Morrow and Gardner (13), Shull (16), East (7), and Collins (5).

Hartley (9) found that in one instance F_1 generation hybrid seed proved 20 percent more productive than either parent. Hayes and East (11) obtained an increase in yield of the hybrid over the parent in five out of seven crosses. The increase varied from 7 to 44 bushels

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[2] Figures in parenthesis refer to publications similarly numbered in the literature cited at the end of this paper.

per acre. Hartley, Brown, et al. (10) obtained increases in yield from some crosses and decreases from some in tests made in Maryland, California, Texas and Georgia. From their results the writers conclude that careful tests must be made in a locality before the farmer can be advised to plant first generation hybrids of certain strains or the pure strains themselves. Belling (2) found that the hybrid seed of Mosby pollinated by Cuban yielded over one-third more shelled corn to the row than did the pure Cuban or Mosby.

All of the results of experiments given above are derived from yields of hybrid seed in the F_1 generation. Collins (6) and also Carrier (3) found that the immediate effect of crossing corn was to increase the yield. Collins (4) found an increase in size of seed the current year when a variety of maize from China was crossed with an American variety. Roberts (14) also reports a noticeable increase in size of hybrid seed over that from the pistillate parent when the Chinese variety of maize used by Collins was pollinated with pollen from an American dent variety, Pride of Saline. In order to obtain further information on the subject, Collins mixed pollen from two varieties of corn and applied it to the silks of one of the varieties, thus obtaining pure and hybrid seed on the same ear. The difference in size of seed produced could be readily noted, as Collins says:

> The hybrid and pure seeds from each of the ears, when weighed separately, exhibited such striking differences that it is thought advisable to place the results on record. In every instance the hybrid seed was larger than the pure seed borne on the same ear, the increase ranging from 3 to 21 percent.

Data from Professor Carrier's (3) experiment conducted at the Virginia station show that in all crosses the immediate effect was to increase the yield. When different strains of Boone County White were crossed there was an increase in yield of from 7.6 to 31.7 percent of crossed over uncrossed seed. The results of this experiment confirm those obtained by Collins. In this experiment, which was completed in the fall of 1914, pollen from two varieties of corn was mixed and used to pollinate the stigmas or silks of one of the varieties, as was done by Collins. In 37 crosses, 26 gave an increase in size of hybrid seed over pure seed, varying from 0.2 to 16.04 percent. In the 11 crosses where there was a decrease, the decrease ranged from 0.3 to 13.45 percent. The average percentage of increase in size was 5.93 percent; of decrease, 5.65 percent.

From the results of the experiments cited above it is advisable, in some cases at least, to cross different strains or varieties of corn to increase the yield. Owing to Mendelian splitting it can not be ex-

pected that the yield of hybrid corn will continue to increase in future generations. Therefore it is good practice to cross such corn every year for the next year's planting,—that is, progeny from the same cross should not be used for more than one generation.

Statement of the Problem.

The purpose of the experiment here reported is to determine the immediate effect of crossing varieties of corn on the size of seed produced and to ascertain whether this method of cross-pollination is advisable from a practical standpoint. Mixed pollen was used to pollinate each ear, so as to eliminate error as far as possible.

Material and Methods Used.

Eight varieties of corn were used in this work, namely, Collier's Excelsior, Casey's Purebred, Boone County Special, Columbian Beauty, Hickory King, Gold Standard, Improved Golden Dent, and Improved Leaming. The first five are white dents and the last three yellow dents. Due to the dominance of yellow over white and double fertilization in maize, called xenia, when white corn is crossed with pollen from a yellow variety the yellow color appears the current year. Thus in each case when both white and yellow pollen is used, we can detect the crossed seed. In crossing yellow varieties with pollen from white varieties, at least in the case of some varieties, the yellow color is diluted and the kernels produced possess a paler color than those fertilized with pollen from a yellow variety.

In making the crosses, paraffined manila paper bags were used for covering tassels and silks. The ears were bagged before or as soon as the silks appeared and the tassels were bagged before any of the pollen had ripened. The ears were pollinated when the silks were about three inches long and the pollination was repeated in one to three days. Each ear was pollinated with pollen from another plant of the same variety, as well as with pollen from the variety with which it was to be crossed, the pollen being mixed in application. The bags were left on the ears until all danger of natural pollination was over.

Results of the Experiment.

The crosses obtained, the number of pure and of hybrid kernels on each crossed ear, the average weights of the pure and the hybrid kernels from each ear, and the percentage of increase in weight from crossing are shown in Tables 1 and 2. Table 1 presents these data

for the crosses in which the female parent was a white and the male parent a yellow variety, while in Table 2 similar data for the crosses of yellow female and white male parents are given.

TABLE 1.—*Number and Average Weight of Pure and Hybrid Kernels Produced from Various Crosses of Corn Varieties in Which a White Female and a Yellow Male Parent Were Used, with the Percentage of Increase in Weight of the Hybrid Over the Pure Kernels.*

Ear Number.	Female Parent.	Male Parent.	Pure Kernels.		Hybrid Kernels.		Increase.
			Number.	Average Weight.	Number.	Average Weight.	
				Grams.		*Grams.*	*Percent.*
1	Hickory King	Improved Leaming	231	0.492	91	0.505	2.64
2	Do.	Do.	62	.473	245	.546	15.43
3	Do.	Gold Standard	300	.495	3	.513	3.63
4	Boone Co. Special	Improved Leaming	3	.293	484	.340	16.04
5	Do.	Improved Golden Dent	416	.342	108	.357	4.38
6	Do.	Gold Standard	20	.450	351	.428	− 5.14
7	Casey's Purebred	Do.	325	.431	24	.381	−13.12
8	Boone Co. Special	Do.	258	.343	196	.367	6.99
9	Casey's Purebred	Do.	171	.376	1	.425	13.03
10	Collier's Excelsior	Do.	169	.400	68	.448	12.00
11	Do.	Do.	163	.460	21	.437	− 5.26
12	Columbian Beauty	Improved Leaming	83	.471	219	.502	6.58
13	Hickory King	Do.	142	.582	31	.513	−13.45
14	Boone Co. Special	Gold Standard	219	.478	23	.506	5.85
15	Casey's Purebred	Do.	164	.391	115	.437	11.76
16	Hickory King	Improved Leaming	37	.596	250	.649	8.89
17	Collier's Excelsior	Gold Standard	15	.291	157	.329	13.05

The evidence of crossing in the crosses recorded in Table 1 was clearly visible, as would be expected because of the dominance of yellow over white and of xenia in maize. In 13 of the 17 crosses the hybrid seeds were the larger, the increase varying from 2.64 to 16.04 percent. In the 4 remaining cases, there was a decrease, this decrease varying from 5.14 to 13.45 percent.

It will be seen in Table 1 that a variety may cause a decrease in size of seed in one case when used as a parent in a hybrid and in another instance the same variety may produce an increase. In 3 of the 4 crosses in which there was a decrease in size of seed Gold Standard is the male parent, but in another cross where Gold Standard is used as the male parent, a large increase is produced. Such contradictory results are difficult to explain in the light of present knowledge.

The evidence of crossing in the crosses recorded in Table 2 was shown by the yellow grains being capped with white or by being a

paler yellow than the pure seed. In many crosses the pure and hybrid seed were difficult to distinguish, but all doubtful seed were weighed with the hybrids. However, these results can not be relied upon to as great an extent as those in Table 1.

TABLE 2.—*Number and Average Weight of Pure and Hybrid Kernels Produced from Various Crosses of Corn Varieties in Which a Yellow Female and a White Male Parent Were Used, with the Percentage of Increase in Weight of the Hybrid Over the Pure Kernels.*

Ear Number.	Female Parent.	Male Parent.	Pure Kernels.		Hybrid Kernels.		Increase.
			Number.	Average Weight.	Number.	Average Weight.	
				Grams.		*Grams.*	*Percent.*
18	Gold Standard	Hickory King	32	0.478	388	0.427	−11.94
19	Do.	Do.	226	.257	487	.277	7.78
20	Do.	Collier's Excelsior	210	.351	342	.344	− 2.03
21	Imp. Golden Dent	Do.	228	.346	350	.331	− 4.53
22	Do.	Do.	76	.413	319	.414	.20
23	Improved Leaming	Boone Co. Special	421	.364	75	.371	1.92
24	Imp. Golden Dent	Collier's Excelsior	265	.406	127	.399	− 1.75
25	Do.	Do.	342	.413	23	.420	1.69
26	Gold Standard	Casey's Purebred	321	.376	54	.375	− .30
27	Improved Leaming	Boone Co. Special	32	.444	210	.446	.45
28	Do.	Do.	33	.445	217	.427	− 4.21
29	Do.	Columbian Beauty	50	.431	172	.432	.20
30	Do.	Boone Co. Special	89	.455	160	.458	.65
31	Imp. Golden Dent	Collier's Excelsior	15	.444	147	.451	1.57
32	Gold Standard	Casey's Purebred	87	.424	160	.435	2.59
33	Imp. Golden Dent	Collier's Excelsior	322	.401	25	.404	.70
34	Improved Leaming	Boone Co. Special	117	.327	110	.339	3.66
35	Do.	Do.	128	.414	244	.417	.70
36	Do.	Casey's Purebred	197	.398	19	.432	8.54
37	Do.	Boone Co. Special	117	.488	29	.507	3.89

In 6 out of 20 crosses there is a decrease in size of seed varying from 0.3 to 11.9 percent. The increase in the remaining 14 crosses varies from 0.2 to 8.54 percent. In 7 instances, the difference in the size of the pure and hybrid seed is so small that we may say that crossing had no effect. In 8 crosses the hybrid seed are substantially increased in size, while in 5 there are rather large decreases.

In Table 2, as in Table 1, those varieties which show a decrease in size of seed in one place likewise give an increase in other crosses. Of the 7 crosses where there is a decrease in size of kernel, Gold Standard is the female parent in 3 and Collier's Excelsior is the male parent in 3.

Selective Pollination and Crowding Out of Seed.

It might be thought that the increase in size of hybrid seed on the same ear with pure seed could be attributed to the stimulus given by cross-fertilization or to lack of development of the pure seed owing to close or self-fertilization. By this stimulation, the hybrid seed may be able to become fertilized more rapidly and then develop sooner and crowd out the pure seed. The above ideas were brought out by Collins (6) and evidence was obtained on the subject from results of an accidental cross. Concerning this cross Collins says:

> An ear of "Maryland White Dent" was pollinated by a plant of the same variety. Seven days later, . . . a plant belonging to a red variety with yellow endosperm was accidentally used as a source of the pollen . . .
>
> In the resulting ear the two kinds of seed were easily distinguished. The pure seeds resulting from the first pollination were pure white, while the hybrid seed resulting from the second pollination were yellow. Unlike the ears where mixed pollen was used, the two kinds of seed were not indiscriminately distributed.
>
> The ear produced 212 white, or pure, seeds and 161 that were yellow, or hybrid. The average weight of the pure seed was 283 grams per 1,000. The average weight of the hybrid seed was 292.5 grams per 1,000, a difference of 9.5 ± 1.06 grams, or 3.4 percent.

On ear No. 2, Hickory King by Improved Leaming, we obtained evidence of a similar nature. In this instance there was only one yellow grain in the last two inches at the tip, the others being uncrossed (pure white). The remainder of the ear showed hybrid seed with the exception of twelve grains. The hybrid seed averaged 0.546 gram per seed, the pure seed at the tip 0.473 gram, and those intermixed with crossed grains 0.475 gram per seed. The grains at the extreme tip were excluded since they are usually smaller than the other grains on the ear.

A Plan for the Production of Pure and Hybrid Seed Corn.

The results from experiments with first generation hybrids in corn and also those from investigations concerning the increased yield due to the immediate effect of crossing corn show that in some instances cross pollination is profitable both to the farmer and seed grower. They may expect, in some crosses, sufficient increase in yield due to the immediate effect of crossing to pay for the extra expense of hybridization. Many experiments have shown that the increase in yield in the F_1 generation has been greater than that of the current year. If the crosses which give a sufficient increase in yield the cur-

rent year also give an increase the following year, the increase obtained the latter time is free of cost.

By a system of planting two desired varieties in alternate rows and detasseling, it is easily possible to produce every year seed of the purebred varieties and at the same time their reciprocal hybrids. The details of such a plan, in different modifications, have been mentioned by Williams (17), East (7), Shull (16), and Collins (5), and need not be repeated here.

In such a plan, different strains of the same variety may be used instead of distinct varieties. The former is probably more advisable, due to the fact that when strains are crossed the parents are not as diverse. The progeny will therefore remain more uniform and segregation of new characters will not take place to the same extent as when varieties are crossed.

Conclusions.

1. The beneficial effect due to crossing varieties in corn frequently appears in the current crop as well as in the first generation, being manifested in the increased weight of the hybrid seeds. In the crosses obtained, 56.8 percent produced profitable increases in yield (weight of kernels) and in 13.5 percent the increase was slight. In 24.3 percent of the crosses, the decrease was marked, and in 5.4 percent it was slight. The largest increase was 16.04 percent, and the greatest decrease 13.45 percent.

2. The farmer or seed grower can make profitable application of these results by mixing seed at planting time. He may get not only an increase the current year but may obtain a larger one the following year.

3. The increases and decreases are not confined to any certain varieties. However, Gold Standard and Collier's Excelsior gave decreased kernel weights in a larger number of crosses than any of the other varieties used.

4. All the crosses were made between distinct varieties and not between strains of the same variety. In a previous experiment at this station (3), larger increases in yield were obtained in the latter case than in this experiment.

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THE PROGRESSIVE DEVELOPMENT OF THE WHEAT KERNEL—II[1]

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INTRODUCTION.

At the meeting of this Society held in Washington, D. C., November, 1913, I read a paper on this subject[2] in which I presented the results of a series of analyses of Turkey and bluestem wheat cut at three-day intervals during the period of kernel formation. That paper contained a historical review of the investigations concerning the changes in chemical composition of the wheat kernel during its development and ripening and an explanation of the reasons for undertaking our own work, which need not be repeated here.

The results obtained in the first year of this investigation were so different than had been expected and opened so many interesting fields of inquiry that it was decided to continue the same general method of investigation through another year, using a larger number of varieties of wheat, securing larger samples each time, and submitting them to somewhat more thorough examination than had been possible with the limited quantity of material which was available in the first year's samples. This was done, and the present paper is a report of the results of this work, the wheat having been grown and the samples secured in the summer of 1914, while the analytical work on the samples has been completed only recently.

EXPERIMENTAL DATA.

Four plots were each seeded to a different variety of wheat to be used in this investigation. At blossoming time, however, it became apparent that the seed which had been used on one of the plots must have been very impure, as the crop was very badly mixed. This plot was, therefore, rejected, and only the other three used for the experimental work. The varieties grown on these three plots were of the fife, velvet chaff,[3] and bluestem groups, respectively.

[1] Presented at the eighth annual meeting of the American Society of Agronomy, Berkeley, Cal., August 9, 1915.

[2] Thatcher, R. W., The Progressive Development of the Wheat Kernel, JOUR. AMER. SOC. AGRON., 5: 203–213. 1913.

[3] The so-called "velvet chaff" wheat used in this experiment is a variety of

The methods of tagging the heads at a uniform stage of development, of sampling at intervals for analysis, and of drying and preparing the grain for analysis were the same as in the preceding year, except that approximately 2,400 heads of each variety were tagged and at each sampling a sufficient number of spikes to yield 100 grams or more of dry matter were taken. The velvet chaff was tagged on July 3, the fife on July 6, and the bluestem on July 7, these being the dates on which the particular variety showed the largest proportion of its spikes with the anthers of the two central spikelets protruding, the proper condition for tagging. The first sample from each variety was taken seven days after the tagging was done, and each successive sampling was done at three-day intervals, care being observed to take the samples at the same hour of the morning each day, so that the intervals were regular and exactly uniform. The yield and certain physical properties of the kernels from each sampling are shown in Table 1.

TABLE 1.—*Yield and Physical Properties of Kernels of Velvet Chaff, Fife and Bluestem Wheats Cut at Successive Stages of Development.*

Sample No.	Date of Cutting.	Average No. of Kernels per Spike.	Weight of 1,000 Kernels.	Dry Matter per 1,000 Kernels.	Specific Gravity of Kernels.	Volume of 1,000 Kernels.
Velvet Chaff:			*gm.*	*gm.*		*c.c.*
2873	July 11	21.1	7.39	6.92	1.4175	5.57
2874	July 14	23.7	10.73	10.03	1.4323	7.49
2875	July 17	23.6	16.15	14.88	1.4344	11.27
2876	July 20	24.3	18.79	17.42	1.4319	13.12
2877	July 23	25.4	22.29	20.50	1.4302	15.58
2878	July 26	22.9	23.75	21.73	1.4185	16.74
2879	July 29	24.1	24.02	22.25	1.4147	16.98
Fife:						
2880	July 14	23.3	6.34	5.96	1.4086	4.50
2881	July 17	21.9	12.21	11.34	1.4266	8.56
2882	July 20	25.1	14.41	13.38	1.4250	10.11
2883	July 23	24.7	18.16	16.61	1.4234	12.75
2884	July 26	26.1	19.42	17.33	1.4115	13.76
2885	July 29	24.4	21.31	19.62	1.4090	15.13
2886	Aug. 1	23.0	21.24	19.20	1.4109	15.15
Bluestem:						
2887	July 15	24.6	6.98	6.47	1.4130	4.94
2888	July 18	24.4	10.94	10.17	1.4367	7.61
2889	July 21	25.2	15.85	14.65	1.4202	11.22
2890	July 24	23.4	21.54	19.85	1.4107	15.27
2891	July 27	26.9	23.29	21.57	1.4102	16.50
2892	July 30	25.5	26.02	23.90	1.4088	18.47
2893	Aug. 2	24.7	27.95	25.23	1.4045	19.91

the group usually known by that name in Minnesota. It is a bearded, smooth-chaffed spring wheat belonging to the group of which the Preston is a typical variety.

The average number of kernels per spike should have been the same in each successive sampling of the same variety if the spikes had been ideally uniform. The variations are not large, however, and indicate a fair degree of uniformity in the spikes as sampled.

Composition of the Dry Matter.

The amount of dry matter per 1,000 kernels and the volume occupied by 1,000 kernels naturally increases with each successive sampling. The increase is not regular, however, the gain in dry matter during some three-day periods being more than double that during other periods of the same length. There is absolutely no correlation between the amount of gain in dry matter per day and the stage of development, except that the most rapid gain was made during the first three-day interval by all three varieties. At subsequent stages of development, rapid and slow accumulation of dry matter appear to alternate. This is probably due to variations in weather conditions. An attempt was made to correlate the rapidity of increase in dry matter with metereological data which had been taken in the same field by another division of the college. No satisfactory correlation could be found, perhaps because of the fact that the three-day intervals were not coincident in the case of all three varieties, or of the difficulty of finding any single meteorological factor which would represent the total influence of weather upon crop development. The amount of evaporation from a wick evaporimeter seemed to be likely to represent most nearly the transpiration effect upon plants; but no correlation of the data of this kind with the increase in dry matter of the wheat kernels during the same period could be found which seemed to be sufficiently close or consistent to justify its presentation here. The results of the analyses of the samples, calculated to the basis of moisture-free material, are shown in Table 2.

Table 2 shows the same regular decrease in percentage of ash, ether extract, and crude fiber, the same fluctuations in the percentage of starch, and the same phenomenon of decreasing percentage of protein in the early stages followed by markedly increasing percentages in the later stages of development, that were found last year. Since these phenomena are exhibited uniformly by each of the five successive series of samples of wheat which have been studied during the two years covered by these invstigations, it seems safe to conclude that they correctly represent the actual course of the changes in percentage of these constituents during the development of wheat kernels

in Minnesota. The changes in percentage of protein in the dry matter are contrary to the general belief concerning the storage of larger proportions of starch during later periods of development, although a few observers have noted the same general tendency toward increased percentage of protein as the kernels approach maturity, as was noted in my former article.

TABLE 2.—*Analyses of Sample Kernels of Velvet Chaff, Fife, and Bluestem Wheats Cut at Successive Stages of Development.*

Sample No.	Date of Cutting.	Percentage Composition of the Dry Matter.						
		Ash.	Protein ($N \times 5.7$).	Ether Extract.	Fiber.	Total Sugars.[1]	Starch.	Undetermined.
Velvet Chaff:								
2873	July 11	2.77	13.03	4.96	5.03	12.54	50.70	10.97
2874	July 14	2.62	12.92	4.36	4.56	4.88	60.30	10.36
2875	July 17	2.47	12.63	3.62	4.51	3.15	62.53	11.09
2876	July 20	2.43	12.30	3.35	3.89	2.33	63.50	12.20
2877	July 23	2.40	12.70	3.33	3.66	1.74	64.45	11.72
2878	July 26	2.44	13.14	3.00	3.83	1.48	63.05	13.06
2879	July 29	2.57	13.29	3.01	3.53	1.62	63.05	12.93
Fife:								
2880	July 14	2.53	13.89	4.26	5.14	10.33	51.85	12.00
2881	July 17	2.40	12.82	3.93	4.64	5.27	59.15	11.79
2882	July 20	2.28	12.64	3.85	4.30	2.47	61.79	12.67
2883	July 23	2.28	13.34	3.62	3.95	1.94	63.78	11.09
2884	July 26	2.15	13.41	3.30	3.78	1.56	63.70	12.10
2885	July 29	2.30	14.18	3.22	4.21	1.36	62.10	12.63
2886	Aug. 1	2.31	15.50	3.13	4.09	1.29	63.40	10.28
Bluestem:								
2887	July 15	2.94	14.20	5.39	5.26	9.08	53.93	9.20
2888	July 18	2.70	13.00	4.04	4.33	7.67	54.84	13.42
2889	July 21	2.42	13.01	3.28	4.08	3.13	61.00	13.08
2890	July 24	2.30	13.91	3.16	4.29	1.56	63.42	11.36
2891	July 27	2.05	14.23	3.16	3.51	1.38	65.11	10.56
2892	July 30	2.01	14.77	3.02	3.83	1.27	64.82	10.28
2893	Aug. 2	2.24	15.62	2.91	3.40	1.08	65.50	9.25

[1] Calculated as dextrose.

Determinations of the total sugars, calculated as dextrose, were made on this year's samples. They show that the very immature kernels contain relatively large proportions of sugars, which decrease rapidly to less than 2 percent of the dry matter at the "milk" stage, and then decrease slightly but regularly until maturity.

The summation of the constituents, as determined, leaves a fairly uniform percentage of "undetermined" material. This probably includes pentosans, and some hemicelluloses of the pericarp material of the kernels. So far as I am aware, there has been no systematic study of the nature of the materials which are not determined in the

regular process of analyses of this kind, but which, in ordinary statements of proximate analysis fall in the group called "nitrogen-free extract" which is determined by difference. This is an interesting problem for future study, which might yield results of considerable theoretical and practical use.

Weights of Materials in the Kernels.

In Table 3 are shown the actual weights of materials present in a kernel of each of the varieties, at each successive stage of growth, as calculated from the percentage composition and the weight of dry matter per 1,000 kernels, as shown in Tables 1 and 2.

Table 3.—*Weight in Milligrams of Material per Kernel of Velvet Chaff, Fife, and Bluestem Wheats Cut at Successive Stages of Development.*

Sample No.	Date of Cutting.	Weight per Kernel in Milligrams.							
		Ash.	Protein (N × 5.7).	Ether Extract.	Fiber.	Total Sugars.[1]	Starch.	Undetermined.	Dry Matter
Velvet Chaff:									
2873	July 11	.192	.902	.343	.348	.868	3.508	.759	6.92
2874	July 14	.263	1.296	.437	.457	.489	6.048	1.039	10.03
2875	July 17	.368	1.879	.539	.671	.468	9.304	1.650	14.88
2876	July 20	.423	2.143	.584	.678	.406	11.062	2.124	17.42
2877	July 23	.492	2.603	.683	.750	.357	13.212	2.402	20.50
2878	July 26	.530	2.855	.652	.832	.321	13.701	2.838	21.73
2879	July 29	.572	2.957	.670	.785	.360	14.028	2.877	22.25
Fife:									
2880	July 14	.151	.828	.254	.306	.615	3.090	.715	5.96
2881	July 17	.272	1.454	.445	.526	.598	6.707	1.337	11.34
2882	July 20	.305	1.691	.515	.575	.330	8.267	1.695	13.38
2883	July 23	.379	2.149	.601	.656	.322	10.594	1.908	16.61
2884	July 26	.383	2.391	.588	.674	.278	11.358	2.157	17.83
2885	July 29	.451	2.782	.632	.826	.267	12.184	2.478	19.62
2886	Aug. 1	.443	2.976	.601	.785	.247	12.173	1.973	19.20
Bluestem:									
2887	July 15	.190	.919	.349	.340	.587	3.489	.595	6.47
2888	July 18	.275	1.322	.411	.440	.780	5.577	1.365	10.17
2889	July 21	.354	1.906	.480	.598	.458	8.937	1.916	14.65
2890	July 24	.426	2.761	.627	.851	.310	12.589	2.285	19.85
2891	July 27	.442	3.069	.681	.757	.298	14.044	2.278	21.57
2892	July 30	.480	3.530	.722	.915	.303	15.492	2.457	23.90
2893	Aug. 2	.565	3.941	.734	.858	.272	16.525	2.334	25.23

[1] Calculated as dextrose.

The figures in Table 3 show that there was a regular increase in the quantity of all the constituents except the sugars, as the kernels developed. The increase in ether extract and fiber is relatively less than that in ash, protein and starch. This is as might be expected,

since the ether extract is made up of the oil from the germ and the coloring matters of the pericarp and contains little material derived from the endosperm, and the fiber comes chiefly from the pericarp. Since the later stages of development consist almost exclusively of filling in of endosperm material, the reason for the observed variations is obvious.

The decrease in actual amount of sugars is undoubtedly due to the rapid conversion of the sugars which enter the seed into reserve starch. Presumably, all of the reserve carbohydrate material which enters the kernel does so in the form of sugars, which are then converted into starch by the endosperm cells. It is evident from these figures that the vegetative portions of the plant actually manufacture sugars and translocate them to the kernel faster than the endosperm cells are able to synthetize them into starch, in the earlier periods of kernel development, but that in later stages starch formation proceeds at a relatively more rapid rate and the proportions of sugars are actually reduced.

Daily Gain of Protein and Carbohydrates.

In Table 4 are shown the actual quantities of protein and of carbohydrates gained by the kernels per day, during each of the successive intervals, and the ratios between these quantities.

Most students of the problem of kernel development have believed that protein is elaborated relatively early in the plant's life and that the larger proportion of material which is first moved into the kernel is protein in character, while the latter filling in is chiefly with starch. Many authors state this as an established fact. Brenchley and Hall,[4] whose results were the immediate cause for the inauguration of our own work along this line, came to the conclusion that the material which the plant moves into the kernel is uniform in composition throughout the period of endosperm-filling. The results which we have obtained, on every one of the five series which have been studied, however, indicate that while the material which the kernel gains from day to day is richer in carbohydrates than the original "mold" into which it enters and continues to be so until about the "milk" stage, usually gaining a little in relative amount of carbohydrates before that stage, the ratio of carbohydrates to protein soon begins to fall off and continues to do so until maturity. It is evident, therefore, that either the material moving into the kernels during later stages of development is richer in protein or that the carbohydrate

[4] Brenchley, W., and Hall, A. D., Jour. Agr. Sci., 3: 195–217. 1909.

material present in the kernel is being destroyed by respiration processes. The latter explanation was suggested by Miss Brenchley to account for the diminished weight of dry matter in the kernels which is nearby always found in the last stages of kernel development. It hardly seems possible, however, that this effect could be sufficient to account for the relative gain in protein which has been found in the later intervals in all of these series.

TABLE 4.—*Gain in Milligrams of Protein and Carbohydrates in Each Kernel of Velvet Chaff, Fife, and Bluestem Wheats per Day, with the Ratio of the Two Materials for Each Period.*

Period.	Gain in Milligrams per Day.		Ratio of Carbohydrates to Protein.
	Protein.	Carbohydrates.	
Velvet Chaff:			
First Sample 7/11	0.902	5.483	6.08
7/11–7/14	0.131	0.850	6.49
7/14–7/17	0.194	1.353	6.96
7/17–7/20	0.088	0.726	8.25
7/20–7/23	0.153	0.827	5.33
7/23–7/26	0.084	0.324	3.86
7/26–7/29	0.034	0.119	3.50
Fife:			
First Sample 7/14	0.828	4.726	5.71
7/14–7/17	0.209	1.481	7.09
7/17–7/20	0.079	0.566	7.17
7/20–7/23	0.152	0.871	5.71
7/23–7/26	0.081	0.329	4.07
7/26–7/29	0.130	0.429	3.29
7/29–8/1	0.068	loss	
Bluestem:			
First Sample 7/15	0.919	5.011	5.80
7/15–7/18	0.134	1.050	7.82
7/18–7/21	0.195	1.249	6.44
7/21–7/24	0.285	1.365	4.82
7/24–7/27	0.103	0.457	4.35
7/27–7/30	0.157	0.597	3.88
7/30–8/2	0.137	0.274	2.00

RELATION BETWEEN COMPOSITION AND SPECIFIC GRAVITY.

After tabulating the data shown in Table 4, it was noticed that there was an apparent correlation between the carbohydrate-protein ratio of the material which entered the kernels and the specific gravity of the resultant kernels. Accordingly, these two sets of data were brought together and are presented in Table 5.

It will be observed that, with only one significant exception, there is a definite correlation between the two sets of data in Table 5 for each series of samples. This affords both an interesting confirma-

tion of the statements of Körnicke and Werner[5] concerning the actual specific gravity of the carbohydrates and protein of the wheat kernel, and a useful check upon the accuracy of the different workers who accumulated the different analytical figures from which these data were calculated.

TABLE 5.—*Relation between Composition of Material Gained by the Kernels and Their Specific Gravity.*

Period.	Bluestem Wheat.		Fife Wheat.		Velvet Chaff Wheat.	
	Carbohydrate-Protein Ratio.	Specific Gravity.	Carbohydrate-Protein Ratio.	Specific Gravity.	Carbohydrate-Protein Ratio.	Specific Gravity.
First sample.....	5.80	1.4130	5.71	1.4086	6.08	1.4175
First 3 days.....	7.82	1.4367	7.09	1.4266	6.49	1.4323
Second 3 days.....	6.44	1.4202	7.17	1.4250	6.96	1.4344
Third 3 days.....	4.82	1.4107	5.71	1.4234	8.25	1.4319
Fourth 3 days.....	4.35	1.4102	4.07	1.4115	5.33	1.4302
Fifth 3 days.....	3.88	1.4085	3.29	1.4090	3.86	1.4185
Sixth 3 days.....	2.00	1.4045	loss	1.4109	3.50	1.4147

CHARACTER OF THE NITROGEN-CONTAINING COMPOUNDS.

Table 6 presents the results of a study of the character of the nitrogen-containing compounds of the samples of bluestem wheat taken at successive stages of growth in this investigation, made by Mr. J. J. Willaman, one of the assistant chemists in our Division of Agricultural Chemistry.

TABLE 6.—*Character of the Nitrogen-Containing Compounds in Bluestem Wheat at Successive Stages of Growth.*

Sample No.	Stutzer's Separation.		Hausmann's Fractions.				
	Albuminoid Nitrogen.	Amid Nitrogen.	Amid Nitrogen.	Humin Nitrogen.	Basic Nitrogen.	Mono-Amino Nitrogen.	Total Recovered.
	%	%	%	%	%	%	%
2887	76.92	23.08	12.55	13.54	21.00	54.31	101.40
2888	85.28	14.72	13.03	9.19	19.49	58.59	100.30
2889	84.69	15.31	13.93	8.55	18.26	57.56	98.30
2890	88.04	11.96	16.02	7.86	18.16	58.08	100.12
2891	88.32	11.68	17.25	7.57	18.22	57.33	100.37
2892	93.15	6.85	17.24	7.76	16.29	58.46	99.75
2893	94.09	5.91	16.31	6.83	16.69	61.43	101.26

It has been known for a long time that the proportion of the nitrogen-containing compounds of any plant material which are precipitated by Stutzer's reagent (cupric hydroxide) and which is com-

[5] Körnicke, F., and Werner, H., Handbuch des Getreidebaues. Berlin, 1884.

monly supposed to represent the completely synthetized "albuminoids" as distinguished from the soluble "amides" which are not precipitated by this reagent, increases as the plant matures. The proportion of "albuminoid" to "total" nitrogen has, therefore, come to be regarded as an index of maturity of the material in question. The figures obtained by Willaman, by the use of the Stutzer's separation, on this set of samples would appear to confirm this opinion. Furthermore, his results from the acid-hydrolysis method of investigation offer an explanation for this change in composition. It has been shown by Osborne[6] that the individual proteins of wheat, when completely hydrolyzed, yield the following widely varying percentages of "amid" or "ammonia" nitrogen: Gliadin, 24.5 percent[7]; glutenin, 18.8 percent; globulin, 7.7 percent; and albumin, 6.8 percent. Gliadin and glutenin are the characteristic endosperm proteins, which united together form the gluten of flour, which has been shown by Blish[8] in some work just completed in our laboratory to yield on hydrolysis approximately 23 percent of its nitrogen as "amid nitrogen." Globulin and albumin, on the other hand, are characteristic pericarp and germ proteins. The regularly increasing percentage of amid nitrogen found in the hydrolyzed proteins of these successive samples of bluestem wheat is, therefore, undoubtedly due to the increasing proportion of gluten-proteins, as the proportion of endosperm in the kernel increases. Similarly, it is probable that the increase of Stutzer's "albuminoid nitrogen" as plants approach maturity is due to the increase of reserve protein food material, as contrasted with vegetative or structural protein.

The data presented in Table 6 clearly show a progressive increase in the proportion of highly organized reserve proteins of the endosperm during the successive stages of growth.

Summary.

The results of two seasons' investigations, including five separate series of successive samplings of the developing wheat kernel, clearly indicate the following changes in composition of the kernel, under Minnesota conditions:

1. The percentage of material matter (ash), ether extract, and crude

[6] Osborne, T. B., The Protein of the Wheat Kernel, Carnegie Institution of Washington, D. C., Pub. No. 84, p. 14. 1907.

[7] Van Slyke's corrected figure for completely hydrolyzed gliadin is 25.5 per cent. We have confirmed this in our laboratory, and find that it agrees with the results from hydrolyzed gluten, reported by Blish.

[8] Blish, Morris J., Jour. Ind. and Eng. Chem., 7 (1915). In press.

fiber in the dry matter progressively decreases. The percentage of sugars also decreases, but much more rapidly during the early stages of development than after the "milk" stage, from which time on the decrease is very slight.

2. The percentage of protein in the dry matter decreases slightly until about the "milk" stage and then begins to increase, the final matured sample usually showing a higher percentage than the very immature ones.

3. The actual quantity of all these materials in the kernels increases during each successive period of growth, with the exception of sugars, of which there is an actual decrease as the kernels develop, undoubtedly by reason of their conversion into reserve starch.

4. The carbohydrate-protein ratio is at first greater and then diminishingly less in the developing kernels than in the "mold" or pericarp material into which the endosperm material is filled.

5. The observed changes in composition of the entire kernel are due, in part at least, to changes in the relative proportions of endosperm, pericarp, and germ, these being parts of the kernel which possess entirely different functions, and correspondingly different chemical composition.

Acknowledgments.

The thanks of the writer are due and are hereby expressed to Mr. C. H. Bailey for assistance in the field work and for determinations of the physical properties of the kernels, to Miss Cornelia Kennedy for the determinations of carbohydrates in the several samples, and to Mr. J. J. Willaman for the use of his data concerning the nitrogen compounds of the several samples.

ON OSMOSIS IN SOILS.[1]

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THE PURPOSE OF THIS WORK.

The results given in previous papers[2] indicate: (1) That clay subsoil acts to a certain degree as a semipermeable membrane when prepared as described below; (2) that water moves through the soil from points at which the soil solution has a low salt content to points at which it has a high salt content. The purpose of the work herein described was to apply many different tests to these phenomena in order to gain new and, if possible, decisive evidence as to whether or not they are due to osmosis. Nine tests were made, which will be described in order.

HOW THE SOIL WAS PREPARED.

Unless otherwise stated, the soil as used in the 9 tests herein described was prepared as follows: 30 g. of moist clay subsoil was placed in a shaker bottle with 150 c.c. of distilled water and 10 drops of strong ammonia. It was shaken for two hours and then boiled gently for half an hour to expel the ammonia. This method of preparation was adopted after tests had been made to determine (1) whether the soil should be shaken with ammonia or without; (2) the minimum effective quantity of ammonia; (3) the minimum effective time of shaking and (4) whether the soil mud should be boiled to expel ammonia. In each test, duplicate tubes were set up as shown in figure 14 and the soil solution was allowed to rise in the measuring tubes until the maximum pressures had developed.

It was found that (1) the pressures were greater when the soil had

[1] Read before the Royal Society of Canada, May 26, 1915.

[2] Lynde, C. J., Osmosis in Soils: Soils Act as Semi-Permeable Membranes, Proc. Amer. Soc. Agron., 4: 102–108. 1912. Also in Jour. Phys. Chem., 16: 759. December, 1912. Lynde, C. J., and Bates, F. W., Further Studies in the Osmosis of Soils, Proc. Amer. Soc. Agron., 4: 108–121. 1912. Lynde, C. J., and Dupré, H. A., Osmosis in Soils: The Efficiency of the Soil Constituents as Semi-Permeable Membranes, JOUR. AMER. SOC. AGRON., 5: 102–106. 1913. Also in Trans. Royal Soc. Canada, 3d series, 7: 105. 1913. Lynde, C. J., and Dupré, H. A., On Osmosis in Soils, JOUR. AMER. SOC. AGRON., 7: 15–19. 1915. Also in Trans. Royal Soc. Canada, 3d series, 8: 133. 1914.

been shaken with ammonia than when it had been shaken without ammonia; (2) the minimum effective quantity of ammonia was 10 drops with 30 g. of subsoil and 150 c.c. of water; (3) the minimum effective time of shaking was 2 hours; and (4) greater pressures were obtained when the soil had been boiled to expel ammonia than when it had not been boiled.

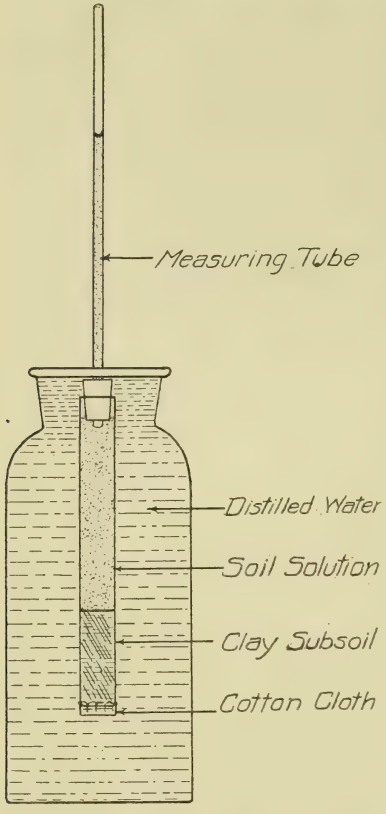

FIG. 14.—Apparatus used in measuring osmotic pressure in soils in the first, third, and fourth tests.

A mechanical analysis of the clay subsoil gave the following results:

Clay	68.8 percent
Silt	19.3 percent
Very fine sand	11.9 percent
Fine sand	0.0 percent
Coarse sand	0.0 percent

Part of the clay consisted of extremely fine particles which on long standing in water assumed a jelly-like appearance; that is, part of the clay was colloidal in nature.

How the Apparatus was Arranged.

The apparatus used in the first, third, and fourth tests was arranged as shown in figure 14; that used in the remaining tests was arranged as shown in figure 15, except in the last part of the ninth test.

The soil mud from one shaker bottle was poured into two tubes, 1.4 cm. inside diameter and 15–20 cm. long, closed at the lower end with one layer of cotton cloth. The tubes were placed in cups of the centrifuge and the cups were filled with water to the level of the mud in the tubes. The centrifuge was run at top speed for about half an hour to settle the soil. The liquid was decanted and more mud was added and settled. This was continued until the desired depth of soil was obtained. The centrifuge made 1,300 revolutions per minute and the middle of the soil columns when settled was 25 cm. from the axis.

The liquid left in the tubes after the last settling was used as the soil solution. The tubes were fitted with measuring tubes, 0.5–1 mm. inside diameter and 45 cm. long, and were then rinsed in distilled water and placed in wide-mouthed bottles filled with distilled water. The water in the bottles was changed daily.

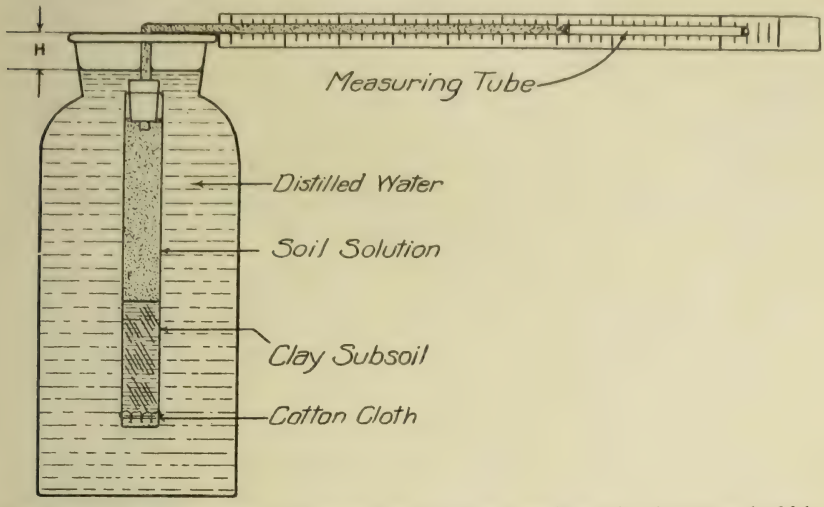

FIG. 15.—Apparatus used in measuring the flow produced in the second, fifth, sixth, seventh and eighth tests and the first part of the ninth test.

When the apparatus was arranged as in figure 14, the bottles were kept full to the brim and the liquid in the measuring tubes at the start was made to coincide with the water level in the bottle. When the apparatus was arranged as shown in figure 15, the water level in the bottles was kept at all times 1.5–2 cm. below the horizontal part of the measuring tubes. This distance (marked H on figure 15) was greater than the capillary lift of the measuring tubes. This was done to eliminate the flow which might be produced by the capillary lift of the tubes.

EXPERIMENTAL WORK.

The tests to which the soil was subjected to determine whether or not the results stated in the first paragraph were due to osmosis will now be described in detail.

TEST 1. IS THE FINAL PRESSURE CONSTANT UNDER GIVEN CONDITIONS?

The theory on which we have been working is as follows: It is possible (1) that soils act as semipermeable membranes; and (2), that water moves through the soil by osmosis.

If this theory is true and if we have tubes set up as in figure 14,

the final pressure produced should be the same, whether the solution in the measuring tubes is started at the water level and allowed to rise or is started at the top of the measuring tubes and allowed to fall. This, on trial, proved to be the case.

Four tubes were set up as in figure 14. The liquid in the four measuring tubes was started, first at zero; next, at a pressure of 42.4 cm. of water; and lastly, again at zero. The final pressures were obtained in each case in about two weeks, but the tubes were allowed to stand one week longer to make sure. These pressures are shown in Table 1.

TABLE 1.—*The Final Pressure, in Centimeters of Water, Obtained in Each Tube in Test 1.*

Starting Point.	Tube 1.	Tube 2.	Tube 3.	Tube 4.	Temperature.
	Cm.	*Cm.*	*Cm.*	*Cm.*	*Degrees C.*
0	13.2	12.1	9.7	14.0	15.8
42.4 cm.	13.8	13.2	9.5	15.0	17.2
0	17.6	16.0	10.9	15.7	17.2

Conclusion.—The final pressures are approximately constant.

TEST 2. IS A FLOW PRODUCED?

If the soil does act to a certain degree as a semipermeable membrane and if the water does move through the soil toward a solution of higher salt content, then if the apparatus is arranged as in figure 15, there should be a flow of the solution along the horizontal measuring tubes. Since, with the apparatus arranged in this way, the maximum pressure can not be produced, the flow should continue as long as the solution in the tubes has a higher salt content than the water outside, unless the soil is altered by the passage of water through it. The results indicate that this is the case.

The four tubes used in the first test were arranged as shown in figure 15, the soil solutions being retained in the tubes. Daily observations of the flow were made for a period of two months. At the end of that time the flow was nearly as strong as at the beginning. The observations were discontinued because other tests had been started to determine the duration of the flow. Table 2 gives the average daily flow for the first five days and for the last five days of the two months.

Conclusions: (1) A flow is produced.

(2) It promises to continue for a long time.

TABLE 2.—*The ily Flow in Linear Centimeters Recorded in Test 2 at the eginning and at the End of Two Months.*

Tim	Tube 1.	Tube 2.	Tube 3.	Tube 4.
	Cm.	*Cm.*	*Cm.*	*Cm.*
A	1.10	1.76	0.88	1.62
At the e	0.92	1.68	0.90	1.30

TEST 3. IS THE MOVEMENT DUE TO COLLOIDAL SWELLING?

We have tried to discover causes other than osmosis which might bring about this movement. It occurred to us that possibly the water does not move through the soil, but that the colloidal clay absorbs soil solution, swells, and thus produces a movement. This did not seem probable in the light of the results obtained in the first and second tests; nevertheless we decided to investigate it as follows:

Four tubes were set up in the usual way, except that solid rubber stoppers were inserted in the bottoms of the tubes in place of the layer of cotton cloth. Thus no movement of water through the soil could take place. If then any pressure developed it must be due, not to osmosis, but to some other cause such as colloidal swelling.

The four tubes were started with a pressure about one-half that which might be expected if they were set up in the regular way. No increase in pressure occurred and, on the contrary, the liquid in the measuring tubes fell to zero in two weeks. The measurements are given in Table 3.

TABLE 3.—*The Pressures in Centimeters of Water at the Beginning and at the End of Test 3.*

Time.	Tube 1.	Tube 2.	Tube 3.	Tube 4.
	Cm.	*Cm.*	*Cm.*	*Cm.*
At the beginning	6.8	8.2	7.4	7.5
At the end	0.8	−0.3	−2.0	−2.0

hen tubes are set up with cotton cloth in the regular way the m...mum pressure remains constant for months if the water is changed daily and if the temperature remains constant.

Conclusion.—Since in this test the pressure did not increase and gradually decrease, it seems clear that the cause of the usual ement is not colloidal swelling.

TEST 4. CAN THE MOVEMENT BE REVERSED?

If the movement is brought about by osmosis, then it should be possible to reverse it by placing the stronger solution outside the tube.

This, on trial, proved to be the case. Two tubes were set up as in figure 14 with soil solution in the tubes. The following tests were made: (1) The tubes were placed in distilled water until some pressure had developed; (2) they were placed in a soil solution stronger than the solution in the tubes and the pressures fell to zero; (3) they were again placed in distilled water and the pressure developed again. The measurements are recorded in Table 4. The electrical resistances at 20° C. were as follows: Of the solution in tube 1, 1,600 ohms; in tube 2, 1,700 ohms; of the strong soil solution, 550 ohms; of $N/50$ KCl solution, 350 ohms.

TABLE 4.—*The Pressures in Linear Centimeters Recorded in Test 4.*

	Tube 1.	Tube 2.	Time.
	Cm.	*Cm.*	*Days.*
In distilled water	4.8	3.3	5
In strong soil solution	0.	0.	5
In distilled water	7.5	7.3	8

Conclusion.—The movement can be reversed and this agrees with the theory that it is produced by osmosis.

TEST 5. HOW LONG WILL THE FLOW CONTINUE?

To determine how long the flow would continue, two tubes were set up as shown in figure 15, and daily observations on the flow were made. The test was started on January 15, 1915, and at this date,

TABLE 5.—*The Daily Flow in Linear Centimeters, the Total Flow to Date in Linear and in Cubic Centimeters, and the Total Flow to Date in Cubic Centimeters per Square Centimeter.*

Period.	Tube 1.	Tube 2.
First 10 days	1.19	0.94
Second 10 days	1.14	1.09
Third 10 days	1.35	1.05
Fourth 10 days	1.21	1.08
Fifth 10 days	.83	.90
Sixth 10 days	1.04	.97
Seventh 10 days	1.22	.96
Eighth 10 days	1.17	.91
Ninth 10 days	1.31	1.13
Tenth 10 days	1.23	0.93
Eleventh 10 days	1.11	0.93
Twelfth 10 days	1.10	0.88
Total flow	139.00	117.70
Total flow	5.28 cc.	4.53 cc.
Total flow per sq. cm.	3.43 cc.	2.55 cc.

May 15, 1915, the average daily flow is almost as great as it was at the beginning. Table 5 gives the average daily flow for each 10-day period, the total flow in c.c., and the total flow in c.c. per square centimeter of soil surface.

Measurements of Tube 1: Depth of soil, 6.5 cm.; inside diameter, 1.4 cm.; area of cross-section, 1.54 sq. cm.; measuring tube, 1 linear centimeter = .038 c.c.; electrical resistance of the solution, 2,700 ohms at 16° C. Measurements of Tube 2: Depth of soil, 6.6 cm.; inside diameter, 1.5 cm.; area of cross-section, 1.77 sq. cm.; measuring tube, 1 linear centimeter = .0385 c.c.; electrical resistance of the solution, 2,700 ohms at 16° C. Electrical resistance of $N/50$ KCl with the same plates, 380 ohms at 18° C. Electrical resistance of distilled water, 50,000 ohms.

Conclusion.—It appears that the flow will continue for a long time.

Test 6. Does the Flow Vary with Change of Temperature?

If the flow is an osmotic phenomenon, an increase in temperature should cause an increase in flow for the following reasons: (1) The osmotic pressure of the soil solution would increase with increase of temperature; (2) the concentration of the soil solution would probably increase with increase of temperature; (3) the viscosity of the water would be decreased with increase of temperature and thus it should move through the soil more rapidly.

To determine how the flow varies with change of temperature, two tubes were set up as shown in figure 15, and the daily flow measured at room temperature in the laboratory and at higher temperatures in an electric oven. The oven could be regulated to within 1° C. The measurements are given in Tables 6 and 7.

Table 6.—*The Average Daily Flow in Linear Centimeters at Different Temperatures and the Viscosity of Water at These Temperatures.*

Temperature.	Tube 1.	Tube 2.	Duration.	Viscosity of Water.
Degrees C.	*Cm.*	*Cm.*	*Days.*	
16.8	3.35	2.48	16	.01100
35.0	4.53	2.17	15	.00720
45.0	6.95	3.10	11	.00597
55.0	8.45	5.65	$2\frac{1}{2}$	.00506
17.3	3.20	2.55	$2\frac{1}{2}$	

Conclusions.—(1) The rate of flow increases with increase of temperature.

(2) The increase is roughly proportional to the increase in fluidity of the water and to the absolute temperature.

TABLE 7.—*The Ratios of the Daily Flow and the Ratios of the Fluidity of Water at These Temperatures.*

Temperature.	Tube 1.	Tube 2.	Fluidity.
Degrees C.			
16.8	1.00	1.00	1.00
35.0	1.35	0.87	1.50
45.0	2.07	1.25	1.80
58.0	2.52	2.27	2.17

TEST 7. HOW DOES THE FLOW VARY WITH CHANGES IN THE CONCENTRATION OF THE SOIL SOLUTION?

To determine this, two tubes were set up as in figure 15. The tubes were first filled with a strong soil solution and the flow measured. The tubes were then emptied and filled with the soil solution diluted to one half, and the flow measured. This was continued until the solution had been diluted to one sixty-fourth of its first strength. The last experiment was made with distilled water in the tubes. The electrical resistance of the solution was taken before and after each experiment. The readings, corrected for changes in temperature during the flow, are recorded in Table 8. The electrical resistance of $N/50$ KCl at 23° C. was 350 ohms.

TABLE 8.—*The Flow in Linear Centimeters per Day and the Electrical Resistance in Ohms at the Beginning and the End of the Experiment.*

Solution.		Tube 1.		Tube 2.		Temperature.
Strength.	Electrical Resistance at Beginning.	Flow.	Electrical Resistance at End.	Flow.	Electrical Resistance at End.	
	Ohms.	*Cm.*	*Ohms.*	*Cm.*	*Ohms.*	*° C.*
1	160	3.7	150	4.7	150	21.3
1/2	295	2.8	255	3.0	200	22.4
1/4	590	2.6	530	2.7	540	20.0
1/8	1,050	2.2	980	2.3	980	18.6
1/16	1,950	2.3	1,875	2.25	1,875	17.2
1/32	3,700	2.45	3,100	2.25	3,300	19.7
1/64	6,200	2.35	5,700	2.1	5,500	18.2
Distilled water.....	25,000	1.95	7,000	1.9	7,000	17.6

Conclusions.—(1) The flow decreases with decrease in concentration of the soil solution.

(2) The resistance of the soil solutions is always less at the end of an experiment than at the beginning. This indicates that the water moves through the soil toward the solution and in so doing carries soluble salts from the soil to the solution. (In this connection it must be stated that the electrical resistances were taken near the top of the tubes in all cases except when distilled water was used.

In this case it was taken near the bottom of the tube. Had the other resistances been taken at this point, it is probable that they would have been lower.)

(3) At low concentrations the flow decreases very slowly with decreasing concentration and there is still a marked flow when distilled water is used instead of soil solution. This is investigated in the eighth test.

TEST 8. WHY IS THERE A FLOW WHEN DISTILLED WATER IS USED AS THE SOLUTION?

It seemed remarkable that a flow should take place with distilled water inside and outside the tube. The explanation which occurred to us and which when tested seemed to be correct is as follows: The lower part of the distilled water in the tube which is in contact with the soil forms a soil solution and this solution on account of its density remains in contact with the soil. That part of the distilled water in the bottle which is in contact with the soil forms a solution and this solution, on account of its density, sinks to the bottom of the bottle and is replaced by fresh distilled water. Thus the liquid just above the soil is a soil solution and the liquid just beneath the soil is nearly pure distilled water, and the flow takes place from the water to the solution.

To test this explanation, we filled the tubes used in the seventh test with fresh distilled water and placed them in small test tubes containing distilled water. The bottoms of the tubes were approximately 1 mm. above the bottoms of the test tubes. Our reasoning was that if the solutions inside and outside the tube had the same concentration there would be no flow, but if they had different concentrations, there would be a flow in the direction of the stronger solution. In the experiment the outside solutions became more concentrated than the inside solutions and the flow was toward the outer solutions. The results are given in Table 9.

It will be noticed that the outer liquids had the greater concentration and that the flow was negative in each case. It will be noticed also that the inside liquids had much higher resistances in

TABLE 9.—*The Negative Flow in Each Tube in Linear Centimeters per Day and the Electrical Resistances of the Solutions in Ohms.*

	Tube 1.	Tube 2.
Flow per day	—0.15 cm.	—2.3 cm.
Electrical resistance of inside solution	25,000 ohms.	55,000 ohms.
Electrical resistance of outside solution	18,000 ohms.	25,000 ohms.

this test than when distilled water was used in the seventh test. This indicates that in the seventh test the water moved up and carried salts from the soil to the inside solutions, but in this test the water moved down through the soil and the soluble salts were carried from the soil to the outer solutions.

Test 9. Does Clay Subsoil in its Natural Condition Act as an Imperfect Semipermeable Membrane?

In the former tests the subsoil has been settled in an artificial manner. The following experiments were made with the subsoil in a more natural condition.

Part 1.—The moist clay subsoil was broken into small lumps and was rammed into the bottom of tubes similar to those used above. Four such tubes were set up as in figure 15. Tube 1 was filled with a strong sugar solution (100 g. granulated sugar in 100 c.c. of water); tube 2 was filled with a saturated K_2SO_4 solution; tube 3 was filled with a medium strong soil solution; and tube 4 was filled with distilled water.

In tube 1 (sugar solution) a flow started at once and still continues (9 days). In tube 2 (K_2SO_4 solution) a negative flow took place for 4 days and since then the flow has been positive. In tube 3 (soil solution) a negative flow occurred for 6 days, and since then the flow has been positive. In tube 4 (distilled water) a very strong negative flow occurred at first, but it is gradually decreasing.

We believe that the negative flow was caused by absorption and we expect the distilled water tube to give a positive flow when the soil becomes saturated. Whether it will do so remains to be seen.

Part 2.—Two tubes were prepared in the same way and filled with the strong sugar solution. Each was then fitted with an open arm mercury manometer and placed in distilled water. Strong pressures have developed in each case. These are recorded in Table 10.

Table 10.—*The Pressures in Centimeters of Mercury and the Duration of the Experiments in Test 9, Part 2, to Date.*

	Pressure.	Duration.
Tube 1	18.3 cm. of mercury	7 days
Tube 2	7.7 cm. of mercury	4 days

General Conclusion.

The results herein reported show that, whatever the cause, water moves through clay subsoil from a weak soil solution toward a strong one. The results agree with the theory that this movement is caused by osmosis.

AGRONOMIC AFFAIRS.

NOTES AND NEWS.

J. T. Barlow of the University of Missouri is now assistant in agronomy in the New Mexico college.

B. H. Hunnicutt, a member of this Society, is director of the newly-organized Agricultural Society of Brazil. It is the intention of the organizers to form corn clubs throughout Brazil similar to those which have been so successful in this country.

Frank S. Kedzie, head of the chemistry department at the Michigan Agricultural College since 1902 and a member of the faculty for 35 years, became president of the college on September 16. He succeeded Dr. J. L. Snyder, who has been made president emeritus. It is understood that Professor Kedzie will act as president only temporarily, pending the selection of a permanent president by the board.

C. V. Ruzek, formerly assistant agronomist in the Arkansas college, now holds a similar position in the Oregon college and station.

Charles E. Thorne, president of this Society during the current year, was doubly honored at Berkeley, Cal., in August by being elected president of the Association of Agricultural Colleges and Experiment Stations and of the Society for the Promotion of Agricultural Science.

The following appointments were effective at the Iowa State College at the beginning of the college year: Ross L. Bancroft of the University of Wyoming as assistant professor of soils; H. W. Johnson of Iowa State College as instructor in soils and assistant in soil bacteriology; and F. S. Wilkins of the University of South Dakota and Roy Westley of Iowa State College as instructors in farm crops. Messrs. Bancroft, Johnson and Wilkins were engaged in graduate work at the Iowa college during 1914–15.

Recent appointments in the department of agronomy in the Pennsylvania State College include Richard A. Andree of the University of Wisconsin as instructor in agronomy and farm mechanics; H. P. Cooper of Clemson College and R. W. Duck of the University of Missouri as assistants in agronomy; D. C. Wimer as assistant in agronomy in charge of laboratory work in soils; and E. O. Anderson of the Michigan Agricultural College as instructor in farm management.

Frank K. Cameron, for the past several years in charge of soil chemistry investigations in the Bureau of Soils, U. S. Department of Agriculture, resigned on November 1 to enter commercial work. The three lines of investigation formerly under his charge have now been separated, R. O. E. Davis having been placed in charge of soil physical investigations and E. C. Shorey, formerly connected with soil fertility investigations in the Bureau of Plant Industry, in charge of soil chemical investigations. The third line, that of investigations of fertilizer resources, has not yet been assigned.

P. T. Meyers has been appointed assistant agronomist of the Wyoming station.

J. B. Sieglinger has been appointed assistant agriculturist in the office of cereal investigations, U. S. Department of Agriculture, and assigned to grain-sorghum and broomcorn investigations at the Woodward, Okla., field station.

The American Association for the Advancement of Science will hold its annual meeting during convocation week, December 27, 1915, to January 1, 1916, at Columbus, Ohio. The retiring vice-president for the Section of Agriculture, L. H. Bailey will deliver an address on the "Forthcoming Situation in Agricultural Work (Part II)." Another vice-presidential address of interest to agronomists is that of G. P. Clinton before the Section of Botany, "Botany in Relation to American Agriculture."

The Second Pan-American Scientific Congress will meet in Washington, D. C., December 27, 1915, to January 8, 1916. George M. Rommel, of the Bureau of Animal Industry, U. S. Department of Agriculture, is Chairman of Section III, Conservation of Natural Resources, Agriculture, Irrigation, and Forestry. Subsections of this Section are as follows: (I) Conservation of Mineral Resources, President C. R. Van Hise of the University of Wisconsin, chairman; (II) Conservation of Forests, Henry S. Graves, Chief of the U. S. Forest Service, chairman; (III) Conservation of Water for Power, N. C. Grover of the U. S. Geological Survey, chairman; (IV) Irrigation, S. Fortier, Office of Public Roads and Rural Engineering, U. S. Department of Agriculture, chairman; (V) Conservation of the Animal Industry, Geo. M. Rommel, Bureau of Animal Industry, U. S. Department of Agriculture, chairman; (VI) Conservation of the Plant Industry, David Fairchild, Bureau of Plant Industry, U. S. Department of Agriculture, chairman; and (VII) Marketing and Distribution of Agricultural Products, Charles J. Brand, Chief, Office of Markets and Rural Organization, U. S. Department of Agriculture, chairman.

REPORT OF THE SECRETARY FOR 1915.

The work of the year has few marked features. Those of most interest are the steady increase in membership of the Society and the more general acceptance of the JOURNAL as a medium of publication, as indicated by the increase in manuscripts submitted. This more abundant material has made possible the more prompt and regular issuance of the JOURNAL. Incident to the increase in membership, the work of the Secretary has materially increased.

It is a pleasure to record the efficient service rendered by Miss J. B. Taylor, the many valuable suggestions received from the former Secretary, Mr. C. R. Ball, and the general cooperation of the members of the Society.

1. FUNDS COLLECTED BY THE SECRETARY.

The following is a classified list of the funds which have been received by the Secretary, chiefly from dues of new members and the sale of the *Proceedings* and JOURNAL. All these have been transmitted to the Treasurer and are included in his annual report.

CLASSIFIED RECEIPTS AND DISBURSEMENTS, NOVEMBER 1, 1914–JULY 22, 1915.

Receipts.

To dues collected (itemized list appended):				
8 new members for 1914	at	$2.00	$ 16.00	
68 new members for 1915	at	2.00	136.00	
7 new members for 1915	at	1.50[1]	10.50	
34 local members for 1915	at	.50	17.00	$179.50
To *Proceedings* and JOURNAL sold:				
9 copies of Volume 1	at	$1.00	$ 9.00	
3 copies of Volume 1	at	2.00	6.00	
11 copies of Volume 2	at	1.00	11.00	
5 copies of Volume 2	at	2.00	10.00	
11 copies of Volume 3	at	1.00	11.00	
7 copies of Volume 3	at	2.00	14.00	
11 copies of Volume 4	at	1.00	11.00	
5 copies of Volume 4	at	2.00	10.00	
9 copies of Volume 5	at	1.00	9.00	
5 copies of Volume 5	at	2.00	10.00	
9 copies of Volume 6	at	1.00	9.00	
6 copies of Volume 6	at	2.00	12.00	
5 copies of Volume 7	at	1.70[2]	8.50	
6 copies of Volume 7	at	2.00	12.00	
8 single numbers of Volumes 5 and 6			2.45	$144.95
				$324.45

[1] Members of local sections who had previously paid dues of 50 cents each as local members.

[2] Sold through agent at 15 percent discount.

Disbursements.

Dec. 2, 1914, by check to Treasurer Roberts	$66.50	
March 1, 1915, by check to Treasurer Roberts	84.45	
April 1, 1915, by check to Treasurer Roberts	87.95	
July 22, 1915, by check to Treasurer Roberts	85.55	$324.45
Balance on hand July 22, 1915		$ 0.00

2. MEETINGS.

Two meetings have been held during the year, a special meeting of the Great Plains section and the present annual meeting.

The special meeting was held at Mandan, N. Dak., in connection with the tenth annual meeting of the Great Plains Cooperative Association, on July 14–16, 1915. There was no separation of the papers or programs of the two associations. About twenty-five papers were presented and about eighty persons attended the sessions. More than half those who presented papers and more than half those in attendance were members of the Society. For the first time, on joint invitation of the secretaries of the two organizations, the Canadian Department of Agriculture was officially represented. The representative, Dr. C. E. Saunders, Dominion cerealist, presented a paper at the meeting.

The present assembly is the eighth annual meeting of the Society. There have been eight papers presented in our separate sessions and seven in joint sessions with the Society for the Promotion of Agricultural Science and the American Farm Management Association. Of the latter, two were by members of this Society. The average attendance at the sessions of this Society has been about forty and at the joint sessions about one hundred.

3. LOCAL SECTIONS.

The Society now has four local sections, located at Cornell University, Iowa State College, Kansas State Agricultural College and Washington, D. C. The Iowa section was organized during the year, with a membership of 28, of whom 19 are members of the general organization. The Washington section reports a local membership of 25, in addition to some 45 members of the general organization. All members of the Cornell University and Kansas sections are members of the Society.

4. MEMBERSHIP.

With each passing year, the membership of the Society steadily increases. It is a pleasure to record that a larger number of members has been added in 1915 than in any previous year. This has been without any special campaign, but is for the most part the result of individuals calling the attention of their coworkers to the Society. Many agronomic workers who are not members would, no doubt, be glad to join with us on request. If the plans of the Society are to be carried out, particularly as to increased frequency of issue of the JOURNAL, a much larger number of members is necessary.

Changed Addresses.

Of the 79 changes of address recorded in the Journal during 1915, 51 were caused by changes of position. This number is 11 percent of the total membership, as compared with 9 percent of similar changes recorded in 1914.

The following is a complete list of those whose addresses are changed in the present issue:

Bartlett, Harley H.
Bolland, Jens
Brown, B. E.
Burgess, P. S.
Cory, Victor L.
Crosby, M. A.
Delwiche, E. J.
Etheridge, W. C.
Frear, D. W.
Gaddis, P. L.
Gaines, E. F.
Garren, G. M.
Goddard, L. H.
Hanger, W. E.
Hendrick, H. B.
Kinney, H. B.
Kinzy, Grover
Krauss, F. G.
Lathrop, Elbert C.
Leth, Robert J.
Miyake, Kōji
Pope, M. N.
Reid, F. R.
Schreiner, Oswald
Sieglinger, J. B.
Skinner, Joshua J.
Suddath, R. O.
Tucker, Geo. M.
Voorhees, John H.
Wentz, John B.
Wermelskirchen, Louis
Woodard, John

New Members.

The total membership at the end of 1914 was 397. To July 22, 81 new members have joined the Society. During the same period 2 have died, 7 have resigned, and 24 have allowed their membership to lapse through nonpayment of dues. The total loss during the year is 33, leaving a net gain of 48 and a present membership of 445.[1] Below is given a list of the new members for 1915. Those marked with the asterisk have joined since the previous issue of the Journal. The addresses of all new members will be found in the address list of members which follows.

New Members for 1915.

Bailey, C. H.
Bancroft, Ross L.
Bassett, L. B.
Benton, T. H.
Beavers, J. C.
Billings, G. A.
Bledsoe, R. Page
Bolland, Jens
Brown, E. B.
Burdick, R. T.
Carnes, Homer M.
Carter, L. M.
Chapman, James E.*
Cobb, J. Stanley*
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Osborn, L. W.
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[1] Since the above was written 26 more new members for 1915 have been received, making a total of 107 for the year, a net gain of 74 and a total present membership of 471.

Pieters, A. J.
Piper, Geo.
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Powers, W. L.*
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Reed, H. R.
Reid, Harold W.
Reinholt, Martin
Rice, Thos. D.
Richardson, A. M.
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Rudolph, E. G.
Russel, J. C.*
Ruzek, C. V.*
Scales, Freeman M.
Schoth, Harry A.*
Scudder, H. D.*
Seamans, Arthur E.
Shiffler, C. W.*
Simard, J. A.
Simmons, Geo. E.
Slipher, John A.
Smith, Herbert G.
Spafford, R. R.
Stemple, F. W.*
Stewart, Geo.
Stoa, Theodore E.
Thomas, Melvin
Thompson, James
Thysell, John C.
Voigt, Edwin
Walster, H. L.
Watson, E. B.
Welch, J. S.
Wentz, John B.
Westover, H. L.
Will, Geo. F.
Wright, R. Claude
Young, M. H.
Young, Y.

Distribution of Membership.

It is believed that a few figures on the distribution of the membership will be of interest. Of the 445 members of the Society, 413 reside within the continental United States. Every State save two is represented by at least one member,[2] and all except six have two or more members. The largest membership, quite naturally, is in the District of Columbia, the total there being 60. The States where the Society is represented by 10 or more members, with the number in each, are as follows: Kansas, 26; Illinois, 21; Iowa, 21; New York, 20; California, 16; Texas, 16; North Dakota, 15; Georgia, 14; Ohio, 13; Indiana and South Dakota, 12; and Minnesota, Missouri, Utah and Wisconsin, 10 each. Five members reside in the insular United States—3 in Hawaii and 1 each in the Philippines and Porto Rico. We have 16 members in Canada, 2 in Cuba, 2 in Brazil, 1 in Mexico and 1 in Costa Rica, thus giving us a fair though very thin distribution throughout the Americas. With three members in Asia, 1 in Africa and 1 in Europe, every continent except Australasia is represented.

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[2] By the acquisition of a new member in one of these States and the removal of a member into the other, the Society on October 15 had at least one member in each of the 48 States.

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Reinholt, Martin, Agricultural College, N. Dak.
Rice, Thos. D., Bureau Soils, U. S. Dept. Agr., Washington, D. C.
Richardson, A. M., Waterville, Wash.
Richey, F. D., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Robb, Newell S., Dept. Agronomy, Idaho Univ., Moscow, Idaho.
Robbins, F. E., 217 Waldron St., West La Fayette, Ind.
Robert, J. C., Agricultural College, Miss.
Roberts, George, Experiment Station, Lexington, Ky.
Roberts, H. F., Experiment Station, Manhattan, Kans.
Roberts, John M., 345 West Michigan St., Chicago, Ill.
Robertson, A. D., Douglas, Ariz.
Ross, John F., Cereal Field Station, Amarillo, Tex.
Rothgeb, B. E., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Rudolph, E. G., care The Dakota Farmer, Aberdeen, S. Dak.
Russel, J. C., McPherson College, McPherson, Kans.
Ruzek, C. V., Experiment Station, Corvallis, Oregon.
Salmon, Cecil, Experiment Station, Manhattan, Kans.
Scales, Freeman M., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Schafer, E. G., Experiment Station, Pullman, Wash.
Schmitz, Nickolas, Agricultural College, College Park, Md.
Schoonover, Warren R., Experiment Station, Urbana, Ill.
Schoth, Harry A., Experiment Station, Corvallis, Oregon.
Schreiner, Oswald, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Schutz, H. H., Southwestern Irrigation Land & Power Co., Los Lunas, N. M.
Scofield, C. S., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Scudder, H. D., Experiment Station, Corvallis, Oregon.
Seamans, Arthur E., Akron Experiment Farm, Akron, Colo.
Shantz, H. L., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Shaw, Chas. F., Experiment Station, Berkeley, Cal.
Shepperd, J. H., Experiment Station, Agricultural College, N. Dak.
Sherwin, M. E., College of Agriculture, West Raleigh, N. C.
Shiffler, C. W., Dept. of Agronomy, Ohio State Univ., Columbus, Ohio.

Shoesmith, V. M., Experiment Station, East Lansing, Mich.
Shutt, Frank T., Central Experiment Farms, Ottawa, Canada.
Sieglinger, J. B., Woodward Field Station, Woodward, Okla.
Simard, J. A., Box 211, Quebec City, Quebec, Canada.
Simmons, Geo. E., Dept. Agron., University of Maine, Orono, Maine.
Skinner, Joshua J., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Slate, W. L., jr., Agricultural College, Storrs, Conn.
Slipher, John A., Purdue University, La Fayette, Ind.
Sloan, Samuel L., Dept. Agronomy, State College, Brookings, S. Dak.
Smith, Herbert G., Experiment Farm, Tucumcari, N. Mex.
Smith, L. H., College of Agriculture, Urbana, Ill.
Smith, Ralph W., Dickinson Substation, Dickinson, N. Dak.
Smith, Raymond S., Dept. Agronomy, State College, Pa.
Snyder, Harry, 1800 Summit Ave., Minneapolis, Minn.
Southwick, Benj. G., Experiment Station, Storrs, Conn.
Southwick, Everett F., Bureau of Agriculture, Manila, P. I.
Spafford, R. R., University Farm, Lincoln, Nebr.
Spillman, W. J., Farm Management, U. S. Dept. Agr., Washington, D. C.
Spragg, F. A., Experiment Station, East Lansing, Mich.
Squires, J. H., Technical Division, Dupont Powder Co., Wilmington, Del.
Stanton, T. R., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Starr, S. H., College of Agriculture, Athens, Ga.
Stemple, F. W., Dept. Farm Crops, Ohio State Univ., Columbus, Ohio.
Stevenson, W. H., Experiment Station, Ames, Iowa.
Stewart, George, Dept. Agron., Agricultural College, Logan, Utah.
Stewart, Robert, University of Illinois, Urbana, Ill.
Stoa, Theodore E., Agricultural College, N. Dak.
Stockberger, W. W., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Stoddart, Chas. W., Dept. Chem., State College, Pa.
Stone, J. L., Dept. Farm Crops, Cornell Univ., Ithaca, N. Y.
Suddath, R. O., Suches, Union Co., Ga.
Summerby, R., Macdonald College, P. Q., Canada.
Sweet, Carl, Sherbrooke, P. Q., Canada.
Taff, P. C., Iowa State College, Ames, Iowa.
Taliaferro, W. T. L., Agricultural College, College Park, Md.
Taylor, F. W., Experiment Station, Durham, N. H.
Thatcher, R. W., Dept. Agr. Chemistry, University Farm, St. Paul, Minn.
Thomas, Melvin, Agricultural College, N. Dak.
Thompson, G. E., Agricultural College, Manhattan, Kans.
Thompson, James, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Thorne, Chas. E., Experiment Station, Wooster, Ohio.
Throckmorton, R. I., Dept. Agronomy, Agricultural College, Manhattan, Kans.
Thysell, John C., Dickinson Substation, Dickinson, N. Dak.
Tinsley, J. D., 507 Union Station, Galveston, Tex.
Tracy, S. M., Biloxi, Miss.
Tucker, Geo. M., States Relations Service, U. S. Dept. Agr., Washington, D. C.
Turlington, J. E., Farm Life School, Vanceboro, N. C.
Tuttle, H. Foley, Experiment Station, Wooster, Ohio.
Umberger, H. J. C., Extension Div., Agricultural College, Manhattan, Kans.
Van Alstine, Ernest, 912 Nevada St., Urbana, Ill.

Veitch, F. P., Bur. Chem., U. S. Dept. Agr., Washington, D. C.
Vinall, Harry N., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Voigt, Edwin, 20 Waldron St., West La Fayette, Ind.
Voorhees, John H., Franklin Farms, Mendham, N. J.
Waldron, L. R., Dickinson Substation, Dickinson, N. Dak.
Wallace, R. C. E., Purdue University, La Fayette, Ind.
Walster, H. L., College of Agriculture, Madison, Wis.
Warburton, C. W., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Wascher, F. M. W., Experiment Station, Urbana, Ill.
Watson, E. B., 17 Budd Hall, Univ. of Cal., Berkeley, Cal.
Wehrle, L. P., Agricultural College, Manhattan, Kans.
Welch, J. S., Gooding Expt. Station, Gooding, Idaho.
Welton, F. A., Experiment Station, Wooster, Ohio.
Wentz, John B., N. Y. State College of Agr., Ithaca, N. Y.
Wermelskirchen, Louis, Experiment Station, College Station, Tex.
Westbrook, E. C., College of Agriculture, Athens, Ga.
Westgate, J. M., Hawaii Experiment Station, Honolulu, Hawaii.
Westover, H. L., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Wheeler, Clark S., 255 West Tenth St., Columbus, Ohio.
Wheeler, H. C., 1018 W. Oregon St., Urbana, Ill.
Wheeler, H. J., Service Bureau, Am. Agr. Chem. Co., Boston, Mass.
Wheeler, W. A., Dakota Improved Seed Co., Mitchell, S. Dak.
Whitcomb, W. O., Agricultural College, Bozeman, Mont.
White, J. W., State College, Pa.
Whiting, Albert L., 504 E. Chalmers St., Champaign, Ill.
Whitson, A. R., Dept. Soils, Univ. of Wisconsin, Madison, Wis.
Wiancko, A. T., Experiment Station, La Fayette, Ind.
Widtsoe, John A., Agricultural College, Logan, Utah.
Will, Geo. F., Bismarck, N. Dak.
Willey, Leroy D., Cheyenne Field Station, Archer, Wyo.
Williams, Chas. Burgess, Experiment Station, West Raleigh, N. C.
Williams, C. G., Experiment Station, Wooster, Ohio.
Willier, J. G., Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Wilson, Bruce S., Experiment Station, Manhattan, Kans.
Winsor, L. M., Experiment Station, Logan, Utah.
Winters, R. Y., Experiment Station, West Raleigh, N. C.
Wood, Caspar A., Agricultural College, College Station, Tex.
Wood, M. W., Boise, Idaho.
Woodard, John, 11 West 29th St., Baltimore, Md.
Woods, A. F., Experiment Station, University Farm, St. Paul, Minn.
Woodworth, C. M., Agricultural Hall, Univ. of Wisconsin, Madison, Wis.
Worrall, Lloyd, Barberton, Transvaal, South Africa.
Worsham, W. A., jr., State College of Agriculture, Athens, Ga.
Worthen, E. L., Experiment Station, State College, Pa.
Wright, Chas. Shannon, Campbell Soup Farm, Riverton, N. J.
Wright, R. Claude, Bur. Plant Indus., U. S. Dept. Agr., Washington, D. C.
Wyatt, F. A., 708 S. 4th St., Champaign, Ill.
Yoder, Malon, 310 Worcester Bldg., Portland, Oreg.
Yoder, P. A., Cairo, Ga.
Young, M. H., Agricultural College, College Station, Tex.

Young, Yungyen, Nanyang Middle School, Shanghai, China.
Youngblood, Bonney, Experiment Station, College Station, Tex.
Zavitz, C. A., Ontario Agr. College, Guelph, Ont., Canada.
Zerban, F. W., 903 Whitney Central Bank Bldg., New Orleans, La.
Zook, L. L., North Platte Substation, North Platte, Nebr.

5. JOURNAL AND PROCEEDINGS.

During the past year, as in 1914, the JOURNAL has been issued bimonthly. The greater volume of material received for publication has made possible the more prompt and regular issuance of the numbers, though there is still something to be desired along this line. At the present time, four numbers have been issued and rather more than enough material is in hand for another without drawing at all on the papers presented at this meeting or at Mandan. Three possibilities for the future present themselves: To refuse publication to some papers which are well worth publishing; to increase the size of the bimonthly issues from 48 to 64 pages; and to increase the frequency of issue. At the present time the most feasible plan seems to be to increase the size of the JOURNAL, when enough papers are in hand, from 48 to 64 pages, and it is believed that the present condition of the treasury will justify this expense. Our ultimate aim should be a monthly publication of at least 48 pages, but at present neither the available material or the size of our membership justifies such a publication. The increased recognition of the JOURNAL as a means of presenting material to the agronomic world is gratifying, and there seems to be little doubt that it will be even more generally used as we are able to increase the promptness and regularity of issuance.

DISPOSAL OF PUBLICATIONS.

In Table 1 will be found full data on the disposal of *Proceedings* and JOURNAL during the period from November 1, 1914, to July 22, 1915.

TABLE 1.—*Data Showing the Original Edition of Each Volume of the Proceedings and Journal, the Distribution Made Previous to and During 1915, and the Number of Copies Remaining in Stock.*

Edition Printed, Disposition of Copies, and Number Remaining.	Volumes.						
	1	2	3	4	5	6	7
Edition printed	501	517	516	514	750	750	750
Previously accounted for	337	341	368	380	606	481	...
Distributed to members, 1915	...	...	...	...	...	...	445
Distributed to subscribers, 1915	...	...	...	...	...	...	41
Sample copies	...	...	...	...	...	...	32
Sold, 1915	12	16	18	16	14	15	13
Total copies distributed	349	357	386	396	620	496	531
Difference	152	160	130	118	130	254	219
Sold on credit orders	...	...	1	1	1	1	2
Copies in stock	152	160	129	117	129	253	217

The figures show a healthy sale of all volumes, without special attention being given to the matter. This source of income is practically all profit to the Society, as each volume is paid for out of current funds. The average number of copies of each volume sold was 15. A considerable part of these copies were sold to members who desired to complete their set of publications of the Society. The income obtained from this source will be used in bettering the JOURNAL and in hastening the day when monthly issuance is possible.

6. MINUTES OF THE ANNUAL MEETING.

BERKELEY, CAL., AUGUST 9–10, 1915.

First Session, Monday Afternoon, August 9.

The meeting was called to order at 2 p.m. by President Thorne and the presentation of papers on the regular program was taken up, as follows:

1. The Progressive Development of the Wheat Kernel (illustrated), by Dr R. W. Thatcher.

2. Smut Explosions and Fires Occurring during Thrashing in the Wheat Fields in Eastern Washington, by Prof. E. G. Schafer (read by the Secretary in the absence of the author).

3. Formation and Classification of the Soils of Arid Regions, by Prof. Chas. F. Shaw.

The reading of the papers being concluded, President Thorne announced two special committees as follows:

NOMINATING COMMITTEE.

W. M. Jardine, *chairman;* R. W. Thatcher and J. W. Gilmore.

AUDITING COMMITTEE.

E. L. Adams, *chairman,* and Geo. R. Hyslop.

After announcements by Mr. C. G. Atwater regarding certain exhibits at the P. P. I. E., and by Secretary Warburton regarding applicants for membership, the payment of dues, handing in papers for editing, and the next session, the sessions adjourned.

Second Session, Monday Evening, August 9.

This session was held jointly with the Society for the Promotion of Agricultural Science and the American Farm Management Association for the presentation of the presidential addresses of the three organizations. It was called to order by President Raymond A. Pearson of Iowa State College, with about 200 persons present. The following papers were presented:

The Foundation of a Rural Civilization, by Dr. H. J. Waters, President of the Society for the Promotion of Agricultural Science.

The Work of the American Agronomist, by Dr. Charles E. Thorne, President of the American Society for Agronomy.

What the Future Holds in Farm Management, by Prof. Andrew Boss, President of the American Farm Management Association (read by Mr. B. H. Crocheron in the absence of President Boss).

After announcements regarding the next sessions of the various organizations, the joint session adjourned.

Third Session, Tuesday Morning, August 10.

The session was called to order by President Thorne at 9 a.m. The reading of papers was resumed, as follows:

4. A Critique of the Hypothesis of the Lime-Magnesia Ration, by Dr. C. B. Lipman.

5. State-wide Crop Improvement, by Mr. J. F. Cox.

6. Relation of Type of Farming to Soil Fertility (illustrated), by Mr. D. A. Brodie.

7. Experimental Methods and Results with Vetch in Oregon, by Prof. Geo. R. Hyslop.

8. Refined Methods of Varietal Testing, by Mr. Frank A. Spragg (read by Mr. J. F. Cox in the absence of the author).

After the reading of Mr. Cox's paper the Society adjourned for a brief period to meet in joint session with the Society for the Promotion of Agricultural Science to listen to an address, "The Trend of Modern Agricultural Practice," by Dr. I. P. Roberts.

The business session followed the reading of Mr. Spragg's paper.

(*Business Session.*)

On motion, the minutes of the last annual meeting as printed in the JOURNAL (6: 276–278) for November–December, 1914, were approved.

The report of the Secretary was read and, on motion, approved.

The report of the Treasurer was read and, on motion, accepted.

The report of the Auditing Committee was read by the chairman, Mr. Adams, and was approved, on motion.

The report of the Executive Committee was read by the Secretary and, on motion, was approved.

In lieu of a report from the Committee on Soil Classification and Mapping, a letter from the chairman, Dr. G. N. Coffey, was read by the Secretary. After remarks by Mr. E. B. Watson approving the suggestions of Dr. Coffey, the report was, on motion, adopted. The suggestion of the chairman with regard to the reduction of the size of the committee was left in the hands of the Executive Committee, with power to act.

The report of the Committee on Agronomic Terminology, in the absence of the chairman and members, was read by the Secretary and, on motion, accepted.

A letter from Prof. C. V. Piper, chairman of the Committee on the Standardization of Field Experiments, stating that the committee had no report to make, was read by the Secretary.

The report of the Committee on Varietal Nomenclature, in the absence of the chairman, Prof. E. G. Montgomery, was read by the Secretary and, on motion, adopted.

The Nominating Committee reported the following nominations for officers of the Society for the year 1916:

President, Mr. C. R. Ball, U. S. Dept. of Agriculture.

First Vice-President, Prof. Alfred Atkinson, Montana Expt. Station.

Second Vice-President, Prof. A. N. Hume, South Dakota Expt. Station.

Secretary, Mr. C. W. Warburton, U. S. Dept. of Agriculture.
Treasurer, Prof. George Roberts, Kentucky Expt. Station.

On motion, the Secretary was instructed to cast the ballot of the Society for the nominees and, this being done, they were declared elected to the respective offices.

A communication from Secretary of State W. J. Bryan inviting the Society to participate in the Second Pan-American Congress, to be held at Washington, D. C., December 27, 1915, to January 6, 1916, was read by the Secretary. On motion, the newly elected president, Mr. C. R. Ball, was named as delegate of the Society to this Congress, and the Secretary, Mr. C. W. Warburton, as alternate.

On motion, the Society expressed its thanks to Dean Thomas F. Hunt and the faculty of the college of agriculture of the University of California for the hospitality extended during its meeting.

The Society then adjourned to meet at 2 p.m.

Fourth Session, Tuesday Afternoon, August 10.

This session was held jointly with the Society for the Promotion of Agricultural Science and the American Farm Management Association. It was called to order at 2 p.m. by Dr. Charles E. Thorne, President of the American Society of Agronomy. The following papers were presented:

The Effect of Time of Seeding on Rate of Seeding Winter Wheat (illustrated), by Director W. M. Jardine.

The Practical Application of Farm-Management Principles (illustrated), by Mr. H. W. Jeffers.

The Farmer's Response to Economic Factors, by Prof. W. J. Spillman.

Intensive Agricultural Practice of China and Japan (illustrated), by Prof. Alfred Vivian.

The Society then adjourned, *sine die*.

REPORT OF THE TREASURER.

From November 9, 1914, to July 31, 1915.

Receipts.

Balance on hand, November 9, 1914		$ 360.06
From the Secretary, C. W. Warburton, per his statements Nos. 1–4		324.45
Membership fees received:		
For 1913	$ 2.00	
For 1914	106.00	
For 1915	512.00	
Fees for collecting checks	.25	620.25
Receipts from libraries for Journal:		
For Volume 5	2.00	
For Volume 6	6.00	
For Volume 7	74.00	82.00
Total receipts		$1,386.76

Disbursements.

1914		Voucher No.	
Nov. 30.	E. B. Thompson Co., rent on stereopticon	58	$ 15.00
Dec. 2.	E. D. Veach, rubber stamp	59	.45
Dec. 2.	Collecting foreign check		.15
Dec. 9.	C. W. Warburton, Secretary's expenses	60	7.80
Dec. 9.	Maurice-Joyce Eng. Co., cuts	61	12.98
Dec. 14.	L. M. Thayer, printing	62	18.75
1915.			
Jan. 23.	New Era Ptg. Co., printing JOURNAL, 6^{4-5}	63	193.95
Feb. 10.	Ky. State Univ. Press, printing	64	5.00
Feb. 10.	Maurice-Joyce Eng. Co., cuts	65	2.00
Feb. 13.	Lexington, Ky., post office, stamps	66	10.00
Mar. 2.	C. W. Warburton, Secretary's expenses	67	34.34
Mar. 16.	L. M. Thayer, printing	68	12.75
Mar. 16.	Maurice-Joyce Eng. Co., cuts	69	2.22
May 5.	Maurice-Joyce Eng. Co., cuts	70	4.60
May 5.	New Era Ptg. Co., printing JOURNAL, 6^{6} and 7^{1}	71	281.59
June 11.	Maurice-Joyce Co., cuts	72	1.00
June 11.	New Era Ptg. Co., printing JOURNAL, 7^{2}	73	115.35
July 15.	New Era Ptg. Co., printing JOURNAL, 7^{3}	74	117.64
July 15.	L. M. Thayer, printing	75	10.25
July 30.	C. W. Warburton, Secretary's expenses	76	22.20
	Total disbursements		$ 868.02
	Balance July 31, 1915		518.74
			$1,386.76

GEORGE ROBERTS,
Treasurer.

AUDITING COMMITTEE'S STATEMENT.

We have examined the accounts and vouchers of the Treasurer and found them correct as reported.

E. L. ADAMS,
GEO. R. HYSLOP,
Auditing Committee.

REPORTS OF COMMITTEES.

The reports of the two special committees, those on audit of accounts and on nominations, are found elsewhere. The Auditing Committee's report immediately follows the report of the Treasurer, while that of the Committee on Nominations appears at the proper place in the minutes of the business session.

The reports of three standing committees, those on soil classification and mapping, on agronomic terminology, and on varietal nomenclature, follow the report of the Executive Committee.

REPORT OF THE EXECUTIVE COMMITTEE.

A meeting of the Executive Committee was called at Washington, D. C., November 12, 1914, by President C. E. Thorne.

On motion, it was ordered that the Secretary act as editor of the JOURNAL for 1915, with C. V. Piper and T. L. Lyon as associate editors for crops and soils respectively, and that the remainder of the board be appointed by the President in consultation with the editor and associate editors.

On motion, it was decided that the next annual meeting of the Society should be held at the same place and on the two days preceding the meetings of the Association of American Agricultural Colleges and Experiment Stations.

On motion, the matter of a referendum vote of the members on an increase of dues, ordered by the previous Executive Committee, was indefinitely postponed, as the present dues were found sufficient to pay the expenses of the Society.

In December, by a mail vote, the Secretary was authorized to arrange for a meeting of the Great Plains section at Mandan, N. Dak., July 14–16, 1915, in connection with the meeting of the Great Plains Cooperative Association.

In February, by a mail vote, the Secretary was authorized to arrange for two joint sessions with the Society for the Promotion of Agricultural Science and the American Farm Management Association, at the Berkeley meetings of the three organizations, August 9 and 10, 1915.

REPORT OF COMMITTEE ON SOIL CLASSIFICATION AND MAPPING.

In lieu of a report from this committee, the following letter from the chairman, Dr. George N. Coffey, was read by the Secretary.

URBANA, ILL., July 1, 1915.

MR. C. W. WARBURTON,

U. S. DEPARTMENT OF AGRICULTURE,
WASHINGTON, D. C.

Dear Mr. Warburton: Replying to your letter of June 25, will say that the Committee on Soil Classification has not been able to do any further work since the meeting in Washington last fall and I do not think that there will be any report at the meeting in Berkeley.

I might say in this connection that it is my personal opinion that the committee is entirely too large to secure the best results and I believe that it would be better to have a committee of three, or not more than five, members and to have this committee made up entirely of men who have had actual field experience in classifying and mapping soils. If you care to present this as a suggestion to the Society, which could be acted upon at the annual meeting, you can do so. It seems to me that the general committee has accomplished about all that a large committee of this nature can hope to accomplish and that it is now time for a few men to take the information collected by this committee and spend considerable time going over it and working out the matter more in detail. It is absolutely impossible to get a large committee together at any other time than the meeting of the Society and then there are always so many things doing that it is impossible to get down to real work.

Yours very truly,

(Signed) GEORGE N. COFFEY,
Chairman.

REPORT OF COMMITTEE ON AGRONOMIC TERMINOLOGY.

For the Committee on Agronomic Terminology I would report that the work of card cataloguing new or little-known terms used in agronomic literature has been continued during the year. In some instances where such terms have seemed especially obscure or unsuited to the use made of them, correspondence with the author of the term has brought out the reason for its use and the meaning intended. Such correspondence and many personal conferences with agronomic workers has shown that there exists a feeling that something on the order of a glossary of new or little-known terms in agronomy would be helpful. The committee has in mind for the coming winter the compiling and publishing in the JOURNAL of tentative lists of such terms, with recommendations as to their usage, and in this way submitting them to the consideration and judgment of the Society.

Respectfully submitted,
For the Committee,
CARLETON R. BALL,
Chairman.

REPORT OF THE COMMITTEE ON VARIETAL NOMENCLATURE.

The Committee on Varietal Nomenclature of the American Society of Agronomy was appointed by the meeting at Columbus, Ohio, in the fall of 1911. At that time, the chairman of the committee pointed out the need of work along this line as a result of some studies which had been carried on at the Nebraska station with some 500 varieties of American oats which had been collected from seedsmen and experiment stations. It was stated at that time that there was evidently very much confusion in names, as different types of oats often had the same name, while the same variety had different names.

While your committee has not felt that it could directly take up the work on this problem, it has nevertheless at each annual meeting submitted a report calling attention to the situation and attempting to encourage those engaged in research to take up work along this line. Since 1911 considerable progress has been made in nomenclature work, and the committee takes this occasion to review the work undertaken or published during the past three years and set forth the present status of the case.

Oats.—In the spring of 1912, the 500 or more samples of oats referred to above which had been growing at the Nebraska station for the three years previous were turned over to Mr. C. W. Warburton of the U. S. Department of Agriculture. He added some new material and the complete collection has since been growing at the Nebraska, Iowa, and Cornell University stations, while a considerable portion of it has been grown under irrigation in southern Idaho. At Cornell Mr. W. C. Etheridge is just now completing three years' study of the varieties and is about ready to publish his thesis on classification. He has also made a very complete review of similar work that has been done in European countries and his work will be of great assistance in clarifying the situation. When further observations and studies have been made by others interested, we should have the nomenclature of oats pretty clearly worked out.

Barley.—Mr. H. V. Harlan of the U. S. Department of Agriculture has been studying the classification of barleys for several years and will probably be ready to publish his work on the classification of barleys within the next year. There are in the country several good collections of barleys which have been studied more or less in cooperation with the U. S. Department of Agriculture. The collection at the University of California and a very similar collection which during the past two or three years has been grown by the Clemens Horst Company of California might be mentioned particularly. These barleys together with the collections from several other sources are also now being grown in the gardens at Cornell University. Upwards of 600 samples have been collected, representing about 300 varieties.

Wheat.—The first attempt to make a classification of wheat in this country was that of Mr. M. A. Carleton, the results of which were published in Bulletin No. 24 of the Division of Vegetable Physiology and Pathology of the U. S. Department of Agriculture. Other studies made by men in that Department have contributed information from time to time on the types and varieties of wheat, especially those of Mr. C. S. Scofield on the classification of durum wheat. Within the past year, Messrs. Carleton, Ball and Clark have planned to make a thorough study and classification of wheat types and varieties. Regarding this work Mr. Ball writes in a recent letter:

"We have under way a classification of American wheats which is progressing rapidly and satisfactorily, considering the size of the job. Some 2,000 to 3,000 varieties, forms, and strains are in the classification nurseries this season at each of three or four different stations, making a total of nearly 10,000 separate rows this year. These include common, club, poulard, Polish, and durum wheats, as also emmer, spelt, and einkorn.

"They are sown in classification arrangement, using 7 characters which were worked out last season. These are, in order, for each group named above, beards, glume color, glume covering (pubescence), beak length, kernel color, kernel size, and kernel density (hardness). This season we are getting full notes on plant and spike characters and this winter in laboratory we will get the more minute kernel characters and of course check on the three we used last winter.

"From a field standpoint the work is already yielding some interesting and helpful results in the way of proving the identity of many local or little-known varieties with standard or widely-known sorts.

"It is a pleasure to record that the staff of the Office of Grain Standardization, so far as they are concerned with wheat, are intensely interested in the problem and are furnishing us with information, samples and assistance which are of the greatest possible help in the promotion of the work.

"The outline of classification prepared last winter comprises 45 typewritten pages and it will be enormously expanded by the work of this season."

The classification of Ohio wheat is being studied by Mr. M. F. Abell at Ohio State University with a collection of about 400 varieties.

Corn.—No serious attempt has been made to classify the varieties of corn since Sturtevant's work published in 1901. However, much new information has since appeared about new types and strains of corn in South America and the southwestern United States and also from the Old World. There is an excellent opportunity for some one to again take up the study and classify

corn, enlarging on Sturtevant's work and also making the classification more detailed by using stalk characters as well as ear characters.

Potatoes.—Mr. William Stuart of the U. S. Department of Agriculture has been for a number of years making a study of American varieties of potatoes and has just published his results in a rather brief form in Department Bulletin No. 176. This is an admirable piece of work and has done a great deal to clarify our knowledge regarding the relationship between our principal varieties and groups of potatoes. We shall look to Mr. Stuart for continued effort along this line in the future.

Other Crops.—In making a review of the present status of the nomenclature of American farm crops we should not fail to mention the excellent classification work on sorghums by Mr. Carleton R. Ball. His work, with the further study by Prof. C. V. Piper, has given us a very excellent idea of the types, varieties and relationship of the members of the sorghum family. Professor Piper's excellent work on the classification of cowpeas, soy beans and members of the velvet bean group has done much to clarify this difficult field. While continued work is needed along all lines which have so far been studied in order to complete and perfect these classifications, there is also much work needed along the lines where little has so far been done. We are especially in need of work in the classification of the economic legumes. The excellent classification made some years ago by Mr. C. D. Jarvis and published in Cornell University Agr. Expt. Sta. Bul. No. 260 should now be enlarged to include a complete classification of American varieties of beans and closely related species. There is also excellent opportunity for work with the alfalfas, clovers, vetches and many other minor groups.

How Shall We Make Use of These Classifications?—As this work on the classification of varieties goes on more practical use should be made of the work. It has been suggested that at least every experiment station in the country should keep growing in their gardens a collection of the type varieties of all important economic plants. The seed of these type varieties should come from some official source in order to know that they are correctly named. With type varieties to work from, it would not be difficult to determine whether the common varieties which are being cultivated are properly named or not. Seedsmen of the country should also be interested in this matter and effort made to see that the commercial varieties that they are putting out are properly named. Those connected with the experiment stations and engaged in plant breeding who from time to time are putting out new selections should observe some simple rules of nomenclature in order not to be giving new names to old standard varieties. The committee still believes that the suggestions made at the last meeting of the Society (Jour. Amer. Soc. Agron., 7: 29–31, 1915) in regard to having an American registry for varieties something on the plan of the herd books which the livestock societies maintain would be an excellent scheme and should serve to keep records of names straight in the future.

E. G. Montgomery,
W. M. Jardine,
A. G. McCall,
Committee.

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